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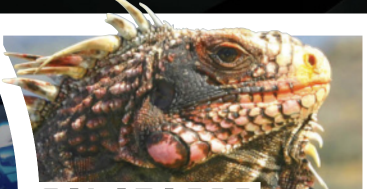
ROBOT WARS

Why giant fighting robots are the next big thing in sports



GALAPAGOS ISLANDS

Home to amazing animals not found anywhere else

SPACE ROCKS

Your guide to planet killers, comets, meteors & more

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Discover which of your organs are only days old!

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ISSUE 79

WELCOME

The magazine that feeds minds!

Page 56
Meet the unusual inhabitants of the Galapagos Islands

We're wheely excited about the 24th Bond outing *Spectre*, so much so that we've dedicated our cover feature to the cool tech that drives his amazing Aston Martin DB10 and other souped-up spy cars. It's been custom-made for the movie and fitted with flamethrowers and an engine that can go from 0-97km/h (0-60mph) in 3.2 seconds.

"[The director] Sam Mendes wanted this to be the poster car for every boy who watched James Bond for the first time," says Aston Martin design director Marek Reichman.

The classic design of this two-door coupe harks back to the one of the most famous cars in the world, the DB5 – as seen with Sean Connery behind the wheel in 1994's *Goldfinger*. There were only ten DB10 models made, but fortunately tech such as run-flat tyres that keep working even after a puncture are features that everyone can get their hands on. Flip forward to page 14 to discover how all this incredible gadgetry works, and more.

I hope you enjoy it as much as the movie! Bada badaaa ba da daaa baaadaaa da dadaaaa...

Jodie

Jodie Tyley
Editor

Meet the team...

Andy
Art Editor
Thanks to 3D printing it looks like we're not far off having a *Star Trek* food replicator, but if eating insects is the future, I'm out.

Katy
Production Editor
Giant, gadget-packed robots fighting with paintballs and crushing claws? That's a sport I could get into watching!

Phil
Staff Writer
Venus flytraps may get all the headlines but they've got nothing on Nepenthes plants; they can catch and eat a rat!

Jackie
Research Editor
Thanks to de-extinction research, we could someday bring long-gone animals *back to life, back to reality...*

Briony
Assistant Designer
Calling all designers! Stuck for pattern ideas? Turn to page 39 for a microscopic image of limpet teeth – you're welcome.

Jo
Features Editor
After researching the future of food, I hope Jackie doesn't start using cricket flour when she bakes for the office.

What's in store

Check out just a small selection of the questions answered in this issue of How It Works...

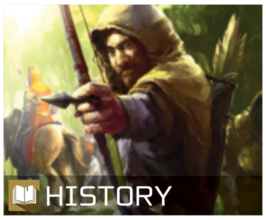
Do odour neutralising sprays actually work? **Page 36**

Where can you find this strange landscape? **Page 62**

Can Porsche's electric car beat Tesla? **Page 26**

How do bladeless fans keep you cool? **Page 54**

How many types of space rock are there? **Page 74**



What did it take to become a medieval outlaw? **Page 80**

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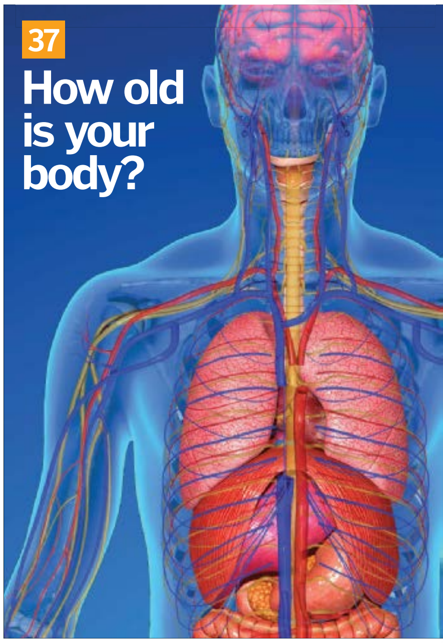

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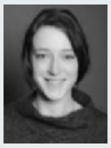
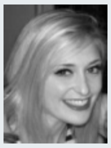


Laura Mears
Laura took on a mammoth task this month, explaining how scientists could bring extinct animals back to life. She also reveals the age of our organs and you'll be pleased to know they're a lot younger than you think!

Gemma Lavender
This month, **All About Space** magazine's Gemma rounds up the craziest facts in the universe. Did you know? The Milky Way is not chocolate, it's rum flavour!



Ella Carter
Our very own David Attenborough was really pleased with her assignment to write about the flora and fauna of the Galapagos Islands, until she realised we weren't paying for a plane ticket. Maybe next time.

Tim Williamson
The Editor of **History Of War** takes us through the art of shooting a longbow on page 81. He even brought one into the office. No one got hurt. Much.

Ceri Perkins
Our New York-based writer reveals how the President stays safe on the mean city streets – with a bevy of vehicles and the latest security tech. Learn more on page 14!

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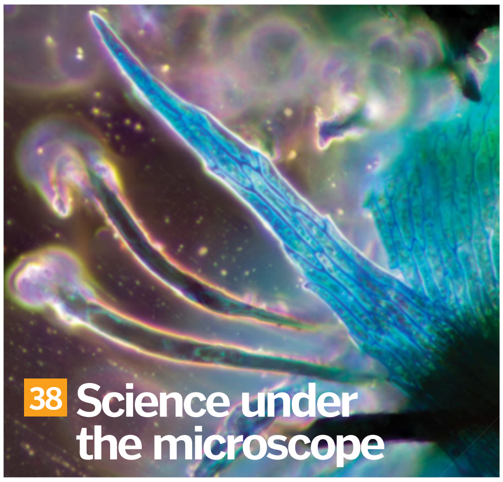

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WATER ON MARS: IS LIFE OUT THERE?
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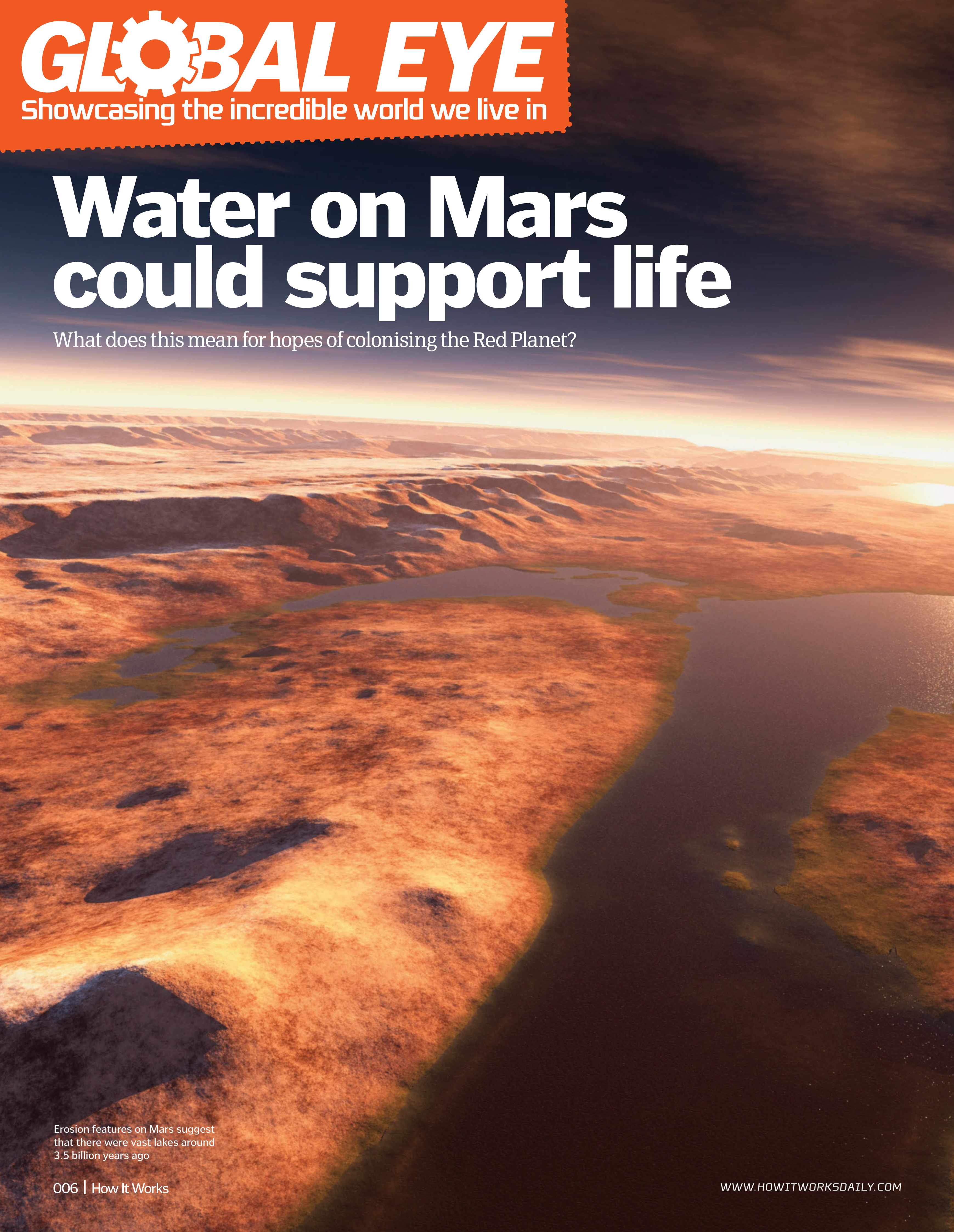
Water on Mars could support life

What does this mean for hopes of colonising the Red Planet?



Erosion features on Mars suggest that there were vast lakes around 3.5 billion years ago

An incredible new discovery from NASA has brought us one step closer to finding life on Mars.

New data from the Mars Reconnaissance Orbiter (MRO) spacecraft has provided the strongest evidence yet that liquid water is flowing on present-day Mars, and where there's water, there is also the possibility of life.

It has long been believed that the Red Planet had a watery past and may even have closely resembled Earth when it first formed. However, as its conditions became more hostile, the rivers and lakes dried up, leaving any remaining water frozen beneath the surface.

Now, NASA scientists have discovered that the planet is still partially wet, with salty liquid flowing down the slopes of its craters. Although only trickling intermittently, this water has the potential to support living organisms. However, these are more likely to be tiny microbes capable of surviving the harsh environment on Mars than the huge alien life forms depicted in science fiction.

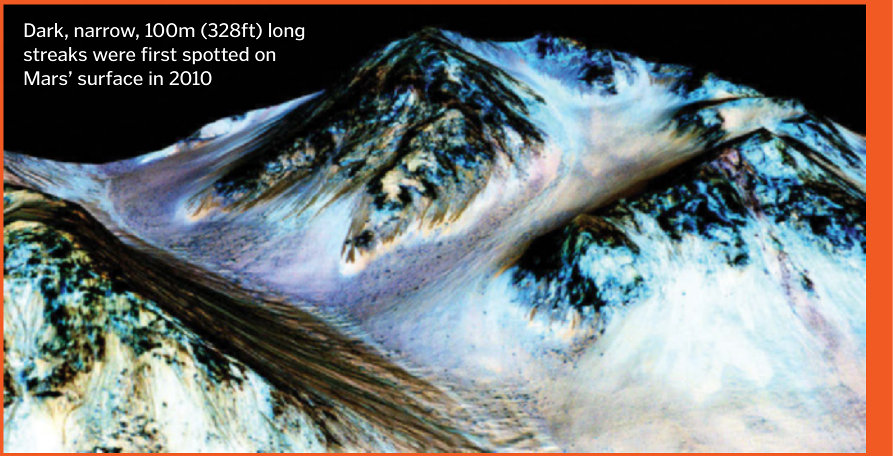
Even if we don't find life already existing on Mars, this discovery is still good news for the future of the ever-expanding human race. Although it would need to be desalinated to make it safe to drink, this water supply could be used to support future human colonies living on the Red Planet. ⚙

How NASA found water on Mars

NASA began to suspect the existence of water on Mars when it spotted mysterious dark streaks on the slopes of the planet's surface. These streaks, which are each roughly the length of a football field, appear during the warmer months, but fade during the colder seasons. This suggests that they are caused by an intermittent flow of liquid.

Using the MRO's instruments to study minerals on the planet's surface, NASA then found hydrated salts on the slopes where the streaks occur. These salts can lower the freezing point of water to -70 degrees Celsius (-94 degrees Fahrenheit), allowing it to remain a liquid during the planet's cold summers but freeze in the even colder winters, thus providing evidence that the streaks are in fact formed by briny water trickling downhill.

However, exactly where this water is coming from remains a mystery, with some speculating that it stored in a reservoir beneath the planet's surface.

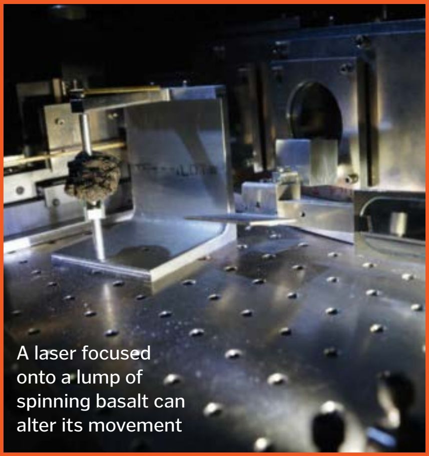


Dark, narrow, 100m (328ft) long streaks were first spotted on Mars' surface in 2010

© Science Photo Library; NASA

Deflecting asteroids with lasers

Saving Earth from space rocks with giant laser beams sounds like the plot of next summer's apocalyptic blockbuster, but it's far from science fiction. Students at the University of California in Santa Barbara are simulating how a laser could be used to deflect asteroids in the lab, on a much smaller scale. They focused a laser onto a spinning lump of basalt – a rock with a similar composition to known asteroids – until it glowed white-hot. This works using a process called sublimation or vaporisation. The heat of the laser turns the rock into a gas, which causes a plume cloud or mass ejection that generates thrust. This enabled them to slow down, stop and then change the rotation direction of the spinning basalt. In space, this would send the asteroid off-course, saving Earthlings from harm.


A laser focused onto a lump of spinning basalt can alter its movement

Double meteorite strike

Earth's only double impact crater has been found

Around 458 million years ago, two enormous meteorites crashed into Earth at the same time, just 16 kilometres (ten miles) apart. It's thought this was the result of a collision between two large asteroids in the asteroid belt between Mars and Jupiter some ten million years earlier, which sent fragments of space rock hurtling towards Earth.

After speeding through our planet's atmosphere, the meteorites landed on what is now known as the Swedish county of Jämtland, but at the time was located 500 metres (1,640 feet) below sea level. The force of the impact would have pushed the water away, leaving the newly formed craters in the seabed completely dry for around 100 seconds before the water came flooding back in.

The larger crater has an enormous diameter of 7.5 kilometres (4.7 miles), while the other is under a tenth of the size at 700 metres (2,300 feet) across. By drilling into the craters, geologists from the University of Gothenburg have discovered that the sequence of sediment above the impact points is identical and of the same age, making it the first double meteorite impact on Earth that has been conclusively proved.

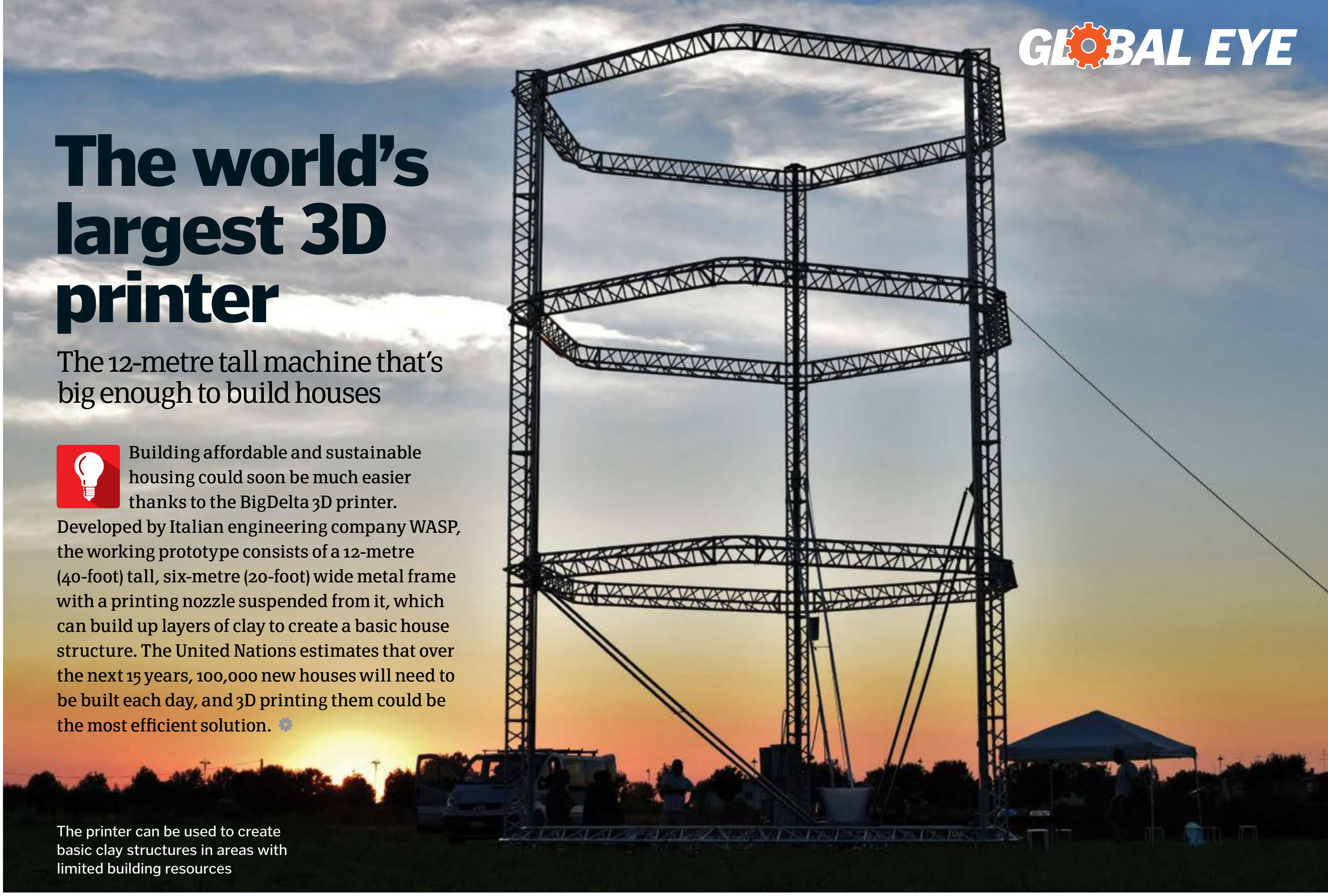
An artist's impression of what the double meteorite impact would have looked like

© Don Dixon/Erik Sturkell, Sonia Fernandez

The world's largest 3D printer

The 12-metre tall machine that's big enough to build houses

Building affordable and sustainable housing could soon be much easier thanks to the BigDelta 3D printer. Developed by Italian engineering company WASP, the working prototype consists of a 12-metre (40-foot) tall, six-metre (20-foot) wide metal frame with a printing nozzle suspended from it, which can build up layers of clay to create a basic house structure. The United Nations estimates that over the next 15 years, 100,000 new houses will need to be built each day, and 3D printing them could be the most efficient solution.

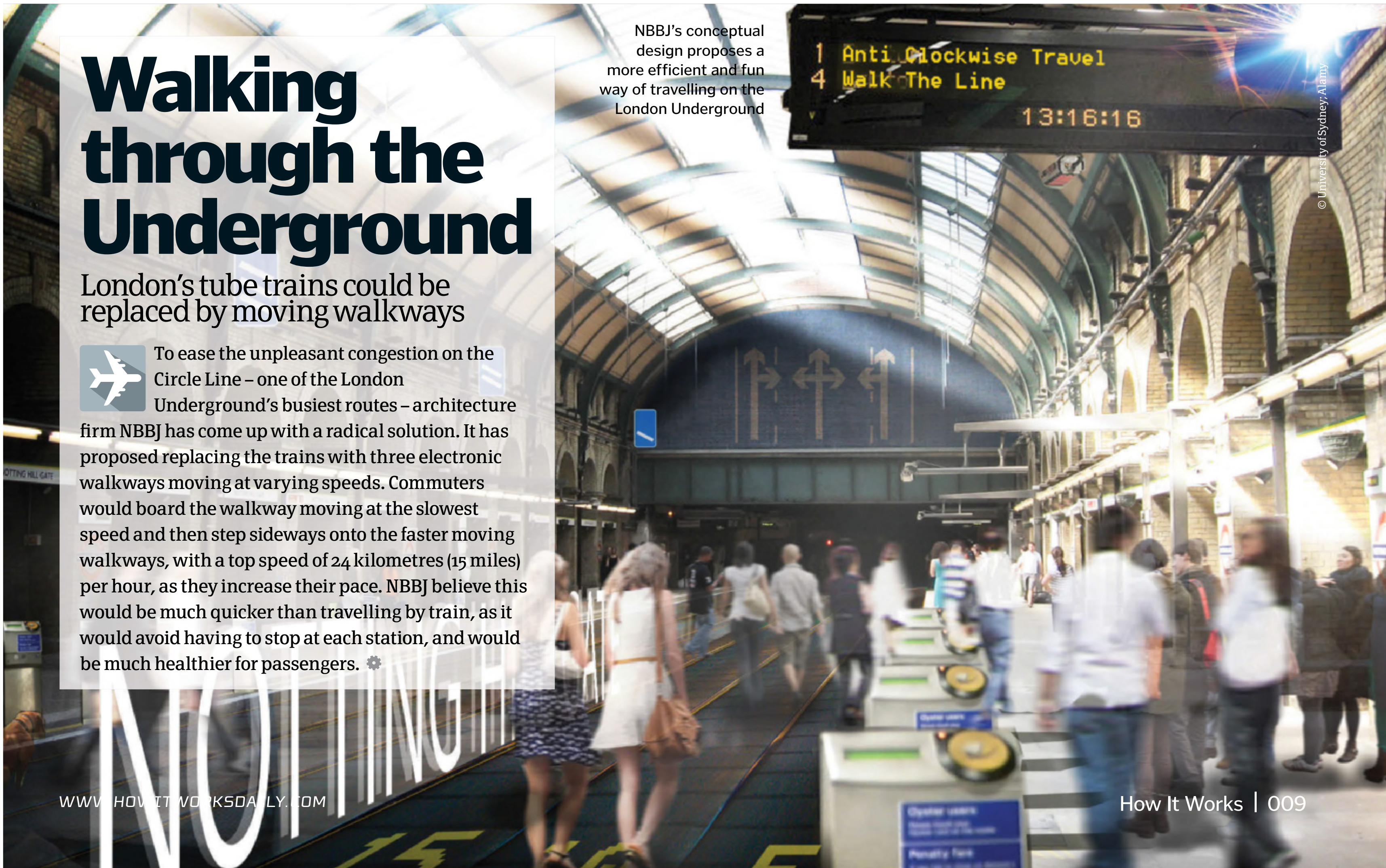


The printer can be used to create basic clay structures in areas with limited building resources

Walking through the Underground

London's tube trains could be replaced by moving walkways

To ease the unpleasant congestion on the Circle Line – one of the London Underground's busiest routes – architecture firm NBBJ has come up with a radical solution. It has proposed replacing the trains with three electronic walkways moving at varying speeds. Commuters would board the walkway moving at the slowest speed and then step sideways onto the faster moving walkways, with a top speed of 24 kilometres (15 miles) per hour, as they increase their pace. NBBJ believe this would be much quicker than travelling by train, as it would avoid having to stop at each station, and would be much healthier for passengers.



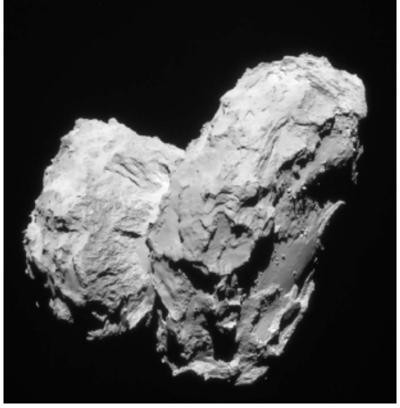
NBBJ's conceptual design proposes a more efficient and fun way of travelling on the London Underground

© University of Sydney; Alamy

10 COOL THINGS WE LEARNED THIS MONTH

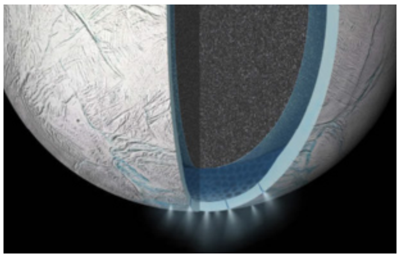
You can hear music through your skull

Rather than blocking out the outside world, Batband headphones allow you to hear the ambient noise around you while you listen to your favourite tunes. They work via bone conduction, transmitting sound waves through your skull so they can bypass your outer ear and travel directly to the inner ear. The headphones can also connect to your device via Bluetooth.



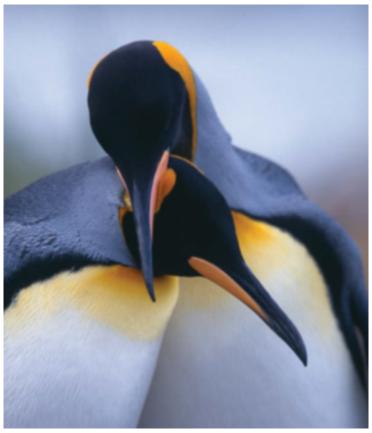
'Rubber duck' comet was formed by a collision

The mystery of how Comet 67P/Churyumov-Gerasimenko obtained its distinctive 'rubber duck' shape has been solved, thanks to new images taken by the Rosetta spacecraft's OSIRIS camera. By studying the layers of material around the comet's nucleus, scientists found that its double-lobed shape must have been caused by the low-speed collision of two separate comets, which then merged together.



Saturn's moon has a hidden ocean

Data from NASA's Cassini mission has revealed that a layer of water separates the crust and core of Saturn's moon Enceladus. By measuring the moon's slight wobble as it orbits Saturn, researchers concluded that its ice shell cannot be frozen to the core, and that water vapour spraying from its south pole must come from a vast liquid reservoir inside.

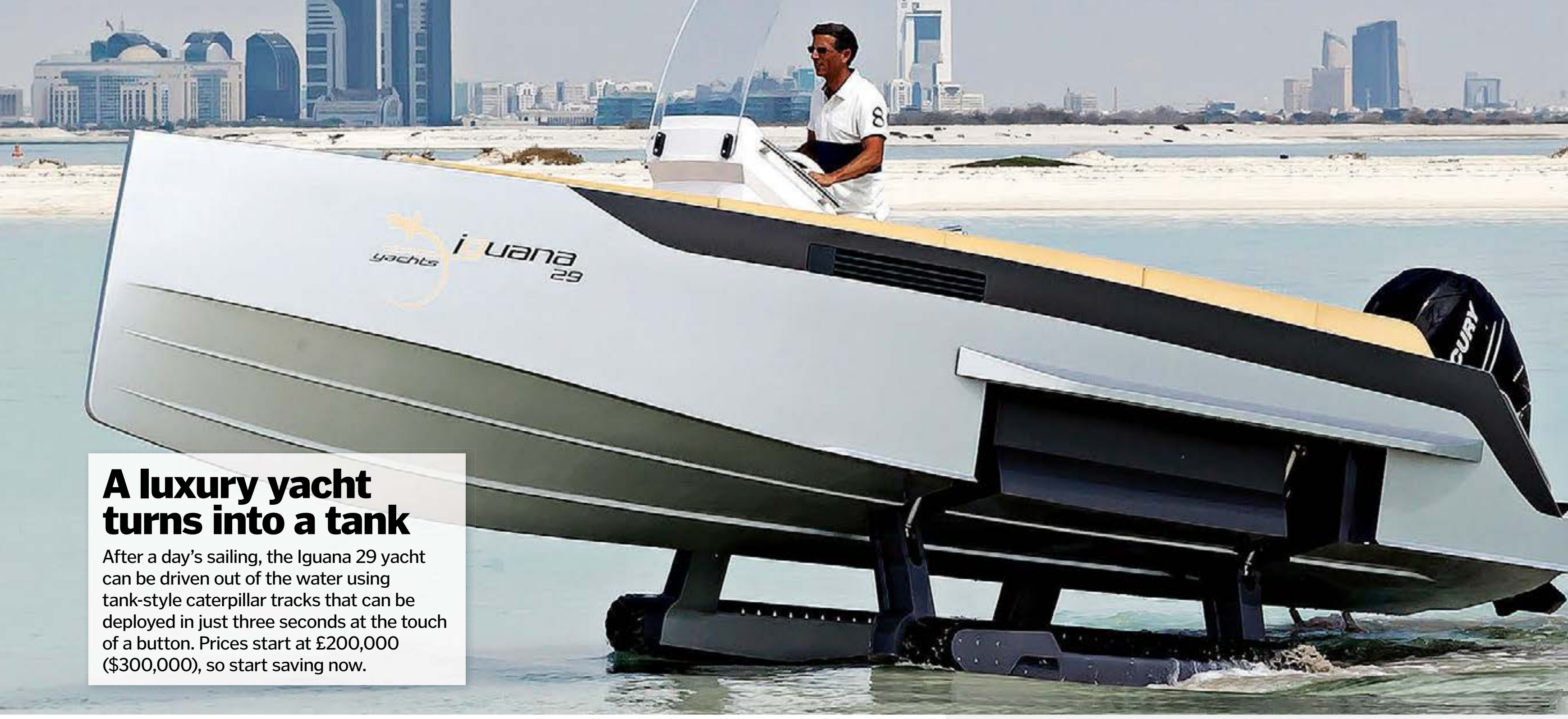


Penguins find each other's beaks sexy

King penguins choose a mate based on beak colour alone, preferring hues that match their own. To us it may look as though their black beaks all have orange patches, but penguins can also see ultraviolet light, revealing other colours that are invisible to human eyes.

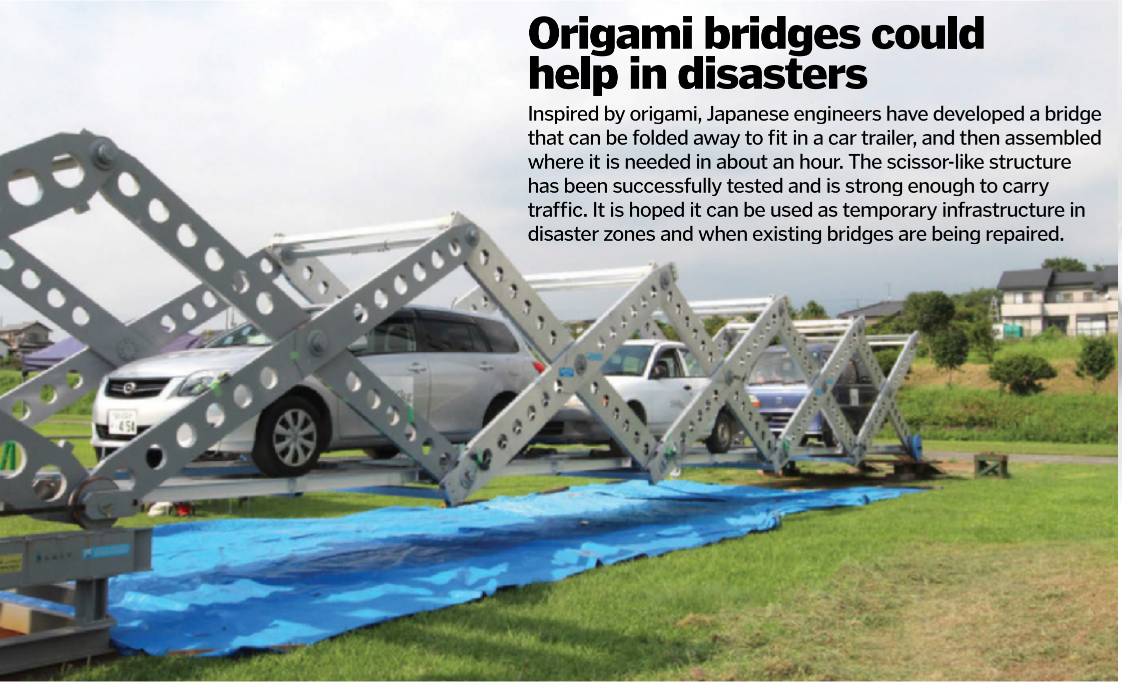
Dogs remember where they bury bones

You may think dogs rely on their incredible sense of smell to find food, but they often use their memory instead. In a recent study, owners placed two cups upside down in front of their dogs and placed a treat under one. After the food was moved to the other cup while the dog's eyes were covered, they still headed straight for the original hiding place, instead of sniffing out its true location.



A luxury yacht turns into a tank

After a day's sailing, the Iguana 29 yacht can be driven out of the water using tank-style caterpillar tracks that can be deployed in just three seconds at the touch of a button. Prices start at £200,000 ($300,000), so start saving now.



Origami bridges could help in disasters

Inspired by origami, Japanese engineers have developed a bridge that can be folded away to fit in a car trailer, and then assembled where it is needed in about an hour. The scissor-like structure has been successfully tested and is strong enough to carry traffic. It is hoped it can be used as temporary infrastructure in disaster zones and when existing bridges are being repaired.

Coffee can cause jet lag

A new study has shown that the caffeine in coffee can slow down your body clock, replicating the same effects as jet lag. Scientists found that drinking a double espresso three hours before bedtime can delay the production of the sleep-inducing hormone melatonin by about 40 minutes, adjusting your body's internal clock and making it more difficult to nod off.

A new bike travels as fast as a car

If you don't fancy pedalling, the GinzVelo bike has a 500-watt, battery-powered motor to help you reach speeds of up to 48 kilometres (30 miles) per hour with minimal effort. It can travel at this speed for 161 kilometres (100 miles) on a single charge and features a fibreglass pod to protect you from the elements.

Gut bacteria can give diet advice

If you want to lose some weight, then identifying the bacteria in your intestines can help you. For the first time, biologists have identified how these bacteria interact when we digest food, enabling them to develop a mathematical formula for predicting which diets will work best for people based on their own unique composition of gut bacteria. This research could help doctors create personalised diets to prevent obesity-related diseases.

©: Thinkstock; Hiroshima University; Rex; NASA; ESA/Rosetta/Navcam

What makes us human?

National Geographic's new series, *Breakthrough*, explores the science of body swapping and more. Professor Henrik Ehrsson gives us a sneak peek

From the invention of the wheel, to the development of antibiotics, history's big scientific breakthroughs have helped shape the world as we know it. But what will the next major discovery be? As part of National Geographic Channel's new *Breakthrough* series, six visionary Hollywood directors are trying to find out.

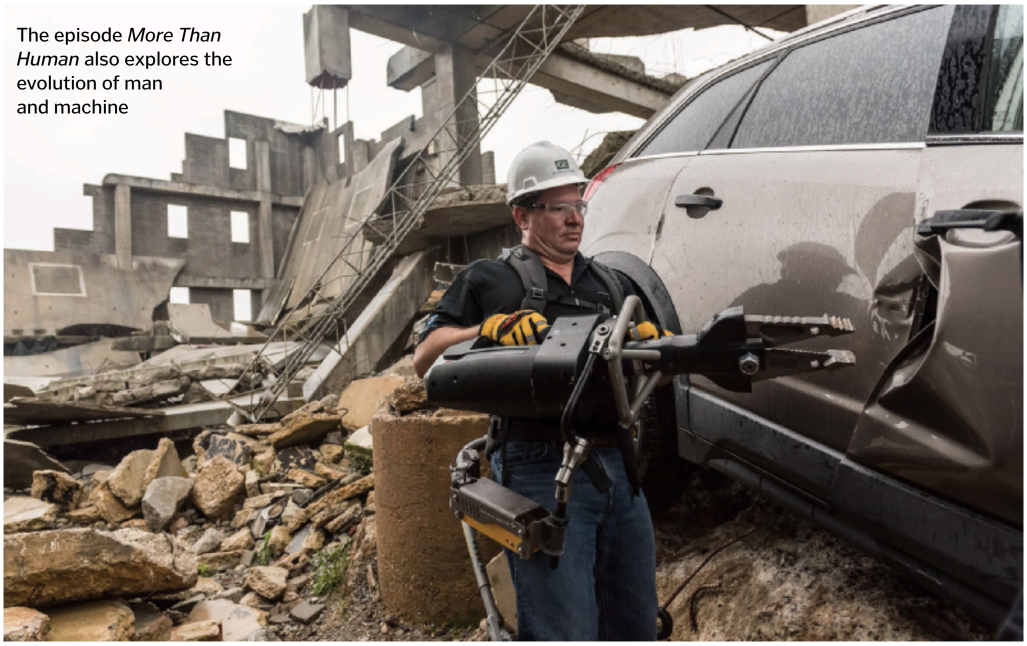
Each episode explores some of the most cutting-edge, life-changing innovations that are happening right now, and the incredible minds behind them. In the episode *More Than Human*, world famous actor Paul Giamatti explores how technology is helping us to evolve and speaks to the people who are questioning what it is that makes us human. One of these people is cognitive neuroscientist Professor Henrik Ehrsson from the Karolinska Institute in Sweden, and we caught up with him to find out about his revolutionary research into how we come to sense that we own our body, and how we can project that sense of self into artificial ones.

What does your work as a cognitive neuroscientist involve?
I am interested in how we experience ownership of our bodies. How do we know what is our body and what is an object in the external world that doesn't belong to our body? This is a complicated task for the brain, as it has to actively generate the experience of your own body. We have studied exactly how this works and what parts of the brain are involved when the brain creates this model of our physical self.

So how does the brain create a sense of self?
We found out that when the brain is updating its model of the body, it uses all available sensory information from the different sensory modalities – visual information from our eyes, touch information from the skin, position information from muscles and joints – and it integrates all this according to certain rules. This integration takes place in the frontal and parietal association cortices of the brain, and we found that activity in these regions is very tightly linked to our subjective experience of our own body.

How have you been able to test this?
We started working on limb illusions, where you experience ownership of a limb, for example a rubber hand, which feels like your own. All of these illusions happen as a consequence of simultaneous, synchronous visual and tactile information. So for example, with the rubber hand, you stroke it and at the same time you stroke the person's real hand, but their real hand is hidden behind a screen on the table. When you stroke them both at the same time, the brain starts to connect what you see and what you feel and update its model of the body. Suddenly you feel someone touching the rubber hand as if it is part of your own body. We then started to think, can we take this to the next level and do experiments with full body illusions, where you sense a completely different body as your own.

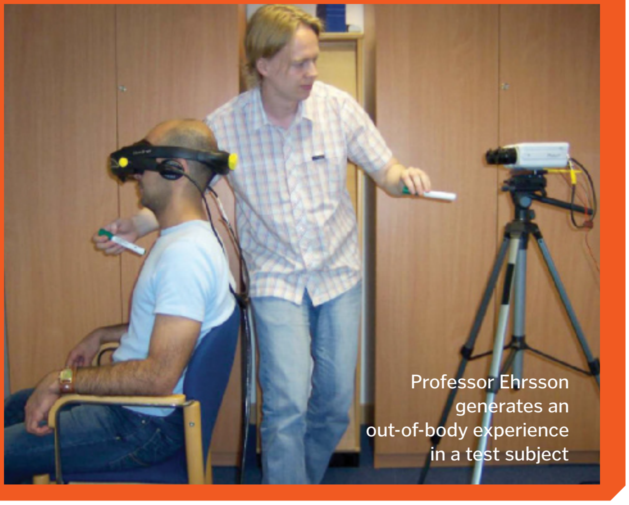
Do these illusions work for everyone?
Around 70 to 80 per cent of the participants will experience these illusions very vividly, but there are some individuals that do not and we are not really sure why. Perhaps the simplest explanation is that all of these illusions happen as a consequence of conflicts between the different senses – the brain has to choose which one it should trust. In most people, vision tends to dominate, so the rubber hand illusion works, but in those individuals that are resistant to it, perhaps their brains rely more on the signals from the muscles and the joints, which is actually the correct perception. We don't know



The episode *More Than Human* also explores the evolution of man and machine

How to create an out-of-body experience

To generate an out-of-body illusion, Professor Ehrsson fits the participant with a head-mounted display that has two screens, one in front of each eye. These screens show live footage from high-resolution video cameras that are placed two metres (6.6 feet) behind them, showing the participant a view of their own back. An object is then moved towards the cameras, just below the field of view, and at the same time, the participant's chest is prodded. Their brain then interprets this visual and tactile information to determine that they are sitting behind themselves in the position of the cameras and looking at a body that is not their own. This simulates the key components of real out-of-body experiences that have been described by neurological and psychiatric patients.



Professor Ehrsson generates an out-of-body experience in a test subject

why this happens, but maybe it's because different brains put different weight on different senses. So if you are a dancer or gymnast who is very much used to sensing the position of your limbs, maybe you would be resistant to the rubber hand illusion that depends on vision.

What are the potential real-world applications of this research?

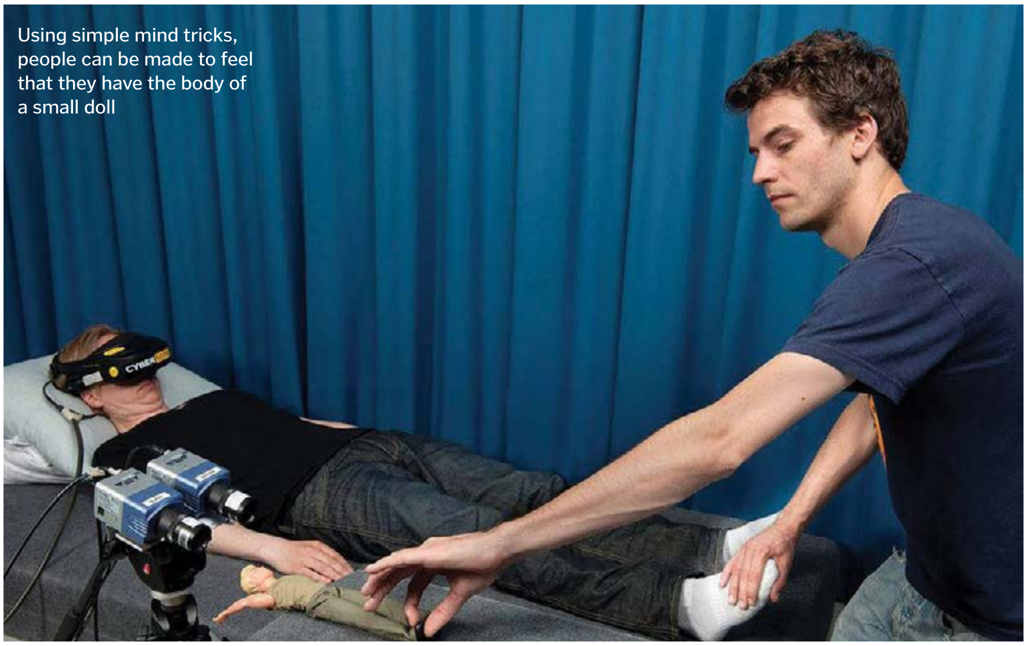
One important application could be the development of next-generation prosthetic limb devices for amputees. There has been a lot of interest in how to create prosthetic limbs that feel like real ones, but this has not yet produced any real clinical applications for patients because it would involve invasive techniques and neurosurgery.

We think that we can use these illusions as a very simple, cheap and non-invasive way of creating artificial limbs that feel real, and have already started such experiments with hand surgeons and engineers at Lund University. The idea is to put stimulators directly on the stump of the amputee and then have sensors in the fingertips of the prosthetic hand. Every time the prosthetic hand touches an object, a signal will be sent to the stimulator on the stump. The brain will then put together what the amputee sees and feels, so instead of feeling touch on the stump, they will feel it projected on the fingers of the prosthetic hand.

Do you think your work is changing the definition of what it is to be human?

Our experience of our human bodies is something that the brain is actively creating on a moment-to-moment basis. You can, for example, experience small dolls as your own body, or virtual bodies as your own, or feel that you have very long arms and all kinds of very weird body deformations. So our physical sense of being human is much more malleable and dynamic than maybe we had thought. We don't really know the ultimate constraints here, such as how 'un-humanlike' a body could be but still feel like your own body. We think that this kind of research challenges one assumption of what it is to be human.

Breakthrough is a six-part series, airing on Sundays at 10pm on the National Geographic Channel, starting on 8 November. Watch *More Than Human* on Sunday 15 November.



Using simple mind tricks, people can be made to feel that they have the body of a small doll

REAL-LIFE BOND CARS

REVEALED: THE GADGET-PACKED, BULLETPROOF RIDES THAT SHIELD SPIES, ROYALS AND WORLD LEADERS

Flamethrowers
The only DB10 gadget revealed so far is a set of powerful flamethrowers that shoot fire from the rear of the car.

> "Aston Martin worked closely with the movie's director to design the DB10"

Not for sale
Aston Martin have only made ten of the cars, and all of them have been used on the set of the movie. Seven were written off in destructive stunts!

Manual transmission
Bond will have to shift gear himself as the car features a six-speed manual transmission unit instead of an automatic gearbox.

DID YOU KNOW? *Casino Royale's Aston Martin performed seven barrel rolls assisted by an air cannon, breaking the world record*

007's new wheels

Meet Bond's sleek and speedy co-star from the latest movie, Spectre

Whether he's chasing down villains or wooing Bond girls, 007's most important gadget is always his car. The new movie is no exception, and will pit the Aston Martin DB10 against the powerful Jaguar C-X75 concept car in an extreme cat-and-mouse chase around the streets of Rome. Aston Martin worked closely with the movie's director Sam Mendes to design Bond's bespoke DB10, but has adopted MI6-level secrecy about the car's features. In the movie trailer, Bond's gadget inventor, Q, says that the two-door coupe has "a few little tricks up her sleeve", but only a few of these have been revealed. Here's what we know so far...

James Bond's high-octane adventures showcase cutting-edge car tech

The new James Bond film *Spectre* sees the world's favourite spy reunited on-screen with his most beloved car brand, the Aston Martin. But of course Bond doesn't drive just any old Aston Martin. The suave secret agent has a long and colourful history of being handed the keys to the most tricked-out, gadget-stuffed ride on the planet – right before he goes and ruins it. But this is all just fantastical fiction, right?

Actually: wrong. A growing number of jittery celebrities – including ex-Spice Girl Mel B and rapper Kanye West – have been investing in armoured vehicles, many of them bristling with features like electric shocking door handles, aimed to deter paparazzi and would-be carjackers. From the outside, these vehicles are indistinguishable from the standard models, but to their occupants they are four-wheeled fortresses that lend them peace of mind as they travel from A to B.

US firm Texas Armoring Corporation (TAC) outfits as many as 100 such "personal protection" vehicles per year. According to CEO Trent Kimball, though, paranoid actors, musicians and sports stars make up only a small minority of the company's clientele. Instead, most of their vehicle upgrades are performed for what Kimball terms "high net worth individuals" travelling in places where there is a very real, very serious kidnap-for-ransom risk. ▶

Aston Martin DB10

The state-of-the-art features, for your eyes only

Up to speed
In the *Spectre* trailer, Q reveals that the DB10 can go from 0-97km/h (0-60mph) in 3.2 seconds.

Under the hood
The car's inner workings are based on those of the V8 Vantage, including its 4.7-litre (1.2-gallon) V8 engine.

THE BEST BOND CAR GADGETS

Ejector seat

In *Goldfinger*, Bond's Aston Martin DB5 is equipped with an ejector seat for swiftly removing any unwanted passengers. The car also has built-in machine guns, tyre spikes and can create a smokescreen to help fend off the enemy.

Rocket boosters

The Aston Martin V8 Vantage Volante's normal engine isn't powerful enough for 007 in *The Living Daylights*, so his is kitted out with a rocket propulsion system. The armrest also has a built in control panel for operating lasers and missiles.

Invisibility cloak

In *Die Another Day*, 007 can evade detection by simply activating the adaptive camouflage of his Aston Martin V12 Vanquish, making it disappear completely. He can then deploy the missiles mounted in the front grille to defeat the bad guys.

Submarine car

007 can navigate land and sea with his Lotus Esprit S1 in *The Spy Who Loved Me*. It swiftly transforms into a submarine when Bond drives it off the end of the pier, then becomes a car again when he reaches the beach.

Remote control

Bond can control his BMW 750iL with his Ericsson mobile phone in *Tomorrow Never Dies*, so he doesn't even need to be behind the wheel. It also has bulletproof windows and electrified door handles to shock any thieves.

Defibrillator

When Bond drinks a Martini spiked with poison in *Casino Royale*, he heads back to his Aston Martin DBS V12 to use its built-in defibrillator machine. A quick shock to the chest helps bring his heart rate back to normal again.

© Thinkstock; Dreamstime; Rex Features

In countries like Nigeria, Cambodia, Venezuela, Honduras, Mexico, Saudi Arabia and Oman, kidnap-for-ransom is an everyday occurrence, explains Kimball. For wealthy business people, entrepreneurs and mid-level executives, investing around $80,000 (approx £53,000) to armour a vehicle that will keep themselves and their families safe not only spares them the emotional turmoil that such an attack would involve – it makes financial sense too.

For these clients, keeping a low profile is paramount; they're keen not to draw attention to themselves with bulky, flashy autos that advertise their status. That's why TAC armours its cars from the inside out, leaving the classic shell of the vehicle in tact, with little hint of its inner strength. "These tend to be luxury vehicles," explains Kimball, "and we want to make sure we put them back as close to the original as possible."

The entire frame of the car is reinforced with cutting-edge materials, including high-hardened ballistic steel, Kevlar, aramid fibres and polyethylene, while the windows are replaced with bulletproof glass. By the time the TAC team is finished, the vehicle is bombproof.

Kimball is so confident in the materials the company uses that he once got behind the wheel of one of their outfitted cars, had an employee aim an AK-47 at his head and instructed them to discharge a round of bullets. Video evidence on YouTube shows Kimball didn't so much as flinch as the bullets cracked lacy patterns into the top surface of the bulletproof glass. James Bond, eat your heart out.

But all that armouring comes at more than just financial cost. There are performance trade-offs as the added weight affects the way the vehicle handles and responds. "Ultimately I need a vehicle that I can turn, that I can stop, that I can do things to manoeuvre out of a kill zone," points out secure transportation expert Joe Autera, who spent over a decade driving high profile clients in some of the most dangerous locations on Earth, and now trains others to do the same.

BMW X5 Security Plus

The first vehicle specifically designed to protect against the world's most widely used firearm, the AK-47

BMW aims to create security vehicles that drive like their normal models

Bullet-resistant glass

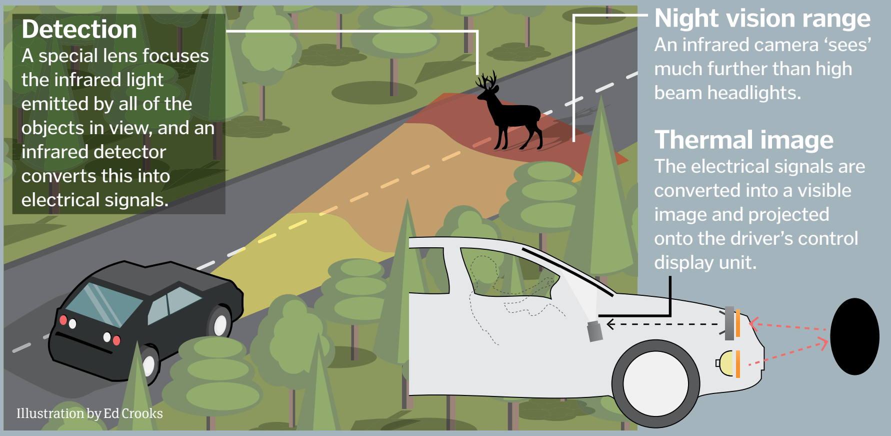
Laminate security glass with a polycarbonate coating protects occupants from bullets and glass shrapnel.

Safety features

The car boasts run-flat tyres, a self-sealing fuel tank, and an attack alarm and intercom system that lets occupants communicate with the outside world without leaving the safety of the vehicle.

How infrared cameras work

Infrared cameras like the BMW Night Vision system allow drivers to perceive their surroundings even in pitch-black darkness. Instead of visible light, which our eyes are built to detect, they 'see' the infrared part of the electromagnetic spectrum. As living things give out heat in this portion of the spectrum, the camera can pick out occupied vehicles and potential human threats.



Detection

A special lens focuses the infrared light emitted by all of the objects in view, and an infrared detector converts this into electrical signals.

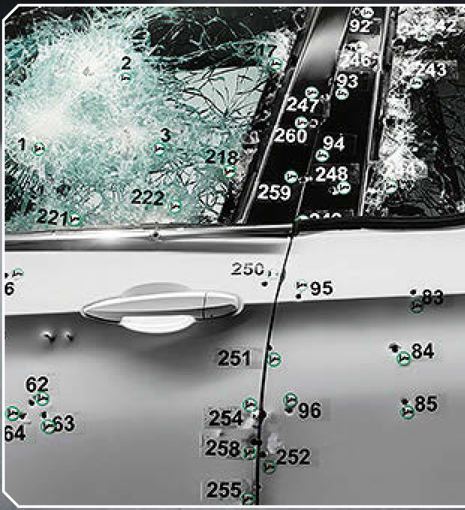
Night vision range

An infrared camera 'sees' much further than high beam headlights.

Thermal image

The electrical signals are converted into a visible image and projected onto the driver's control display unit.

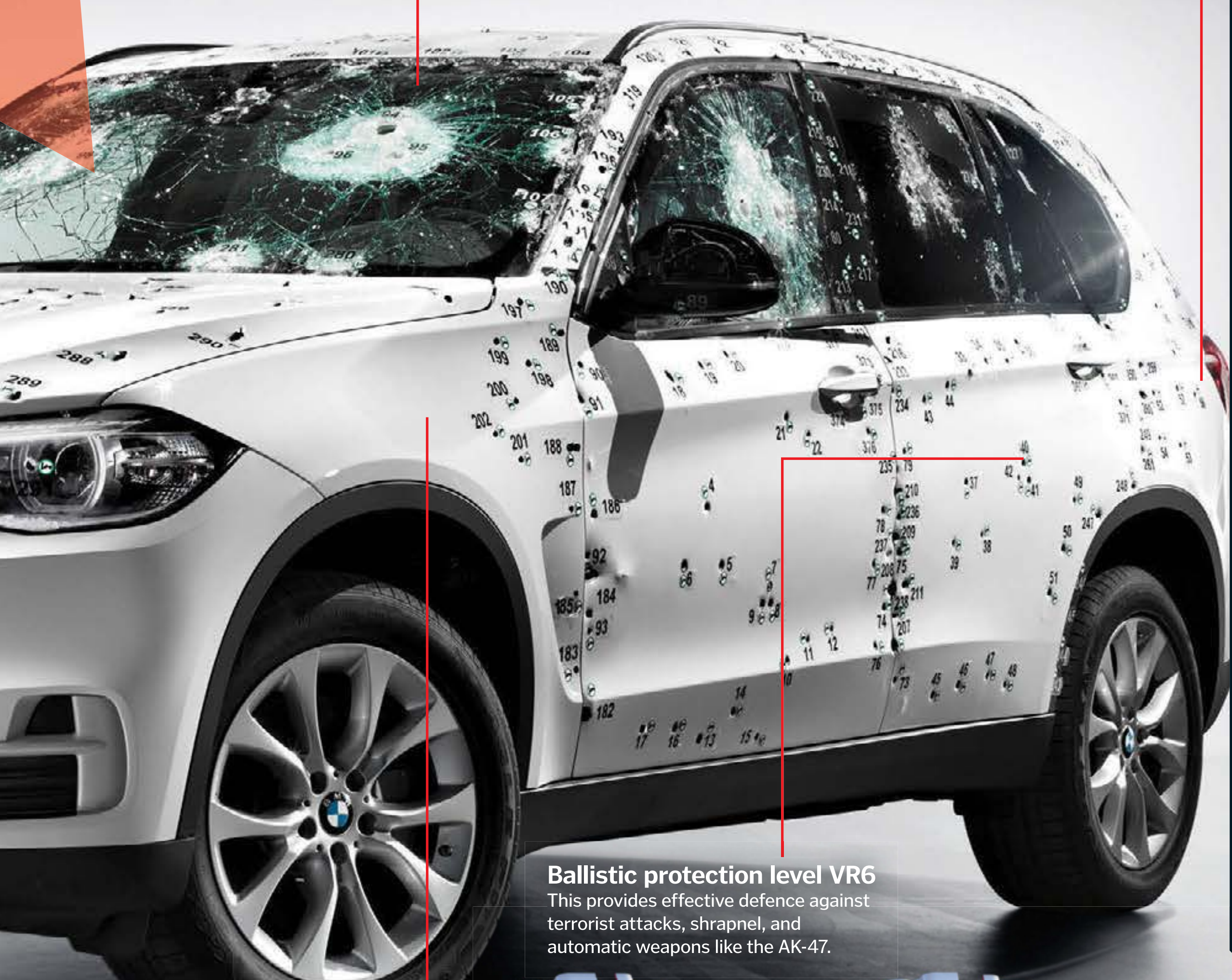
Illustration by Ed Crooks



DID YOU KNOW? *The most popular armoured vehicles on the market today are the Toyota Land Cruiser and the Lexus LX570*

Interior
Inside, the car is fully equipped with BMW's renowned luxury features and finishing.

BMW xDrive
An all-wheel drive system adapts to all surfaces and conditions, redistributing power between the front and rear axles accordingly for maximum traction and control.



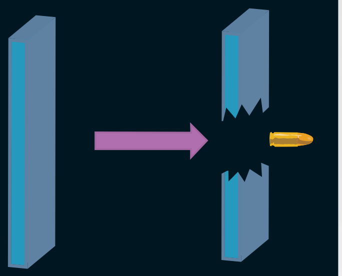
Ballistic protection level VR6
This provides effective defence against terrorist attacks, shrapnel, and automatic weapons like the AK-47.

Armour
Passenger cell protected by a steel armour sheath; aramid and polyethylene sealed joints provide protection where body panels meet.

How bulletproof glass works

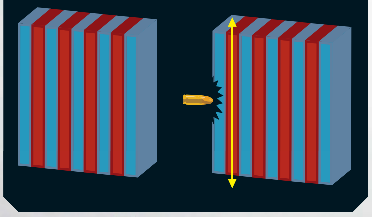
Ordinary glass

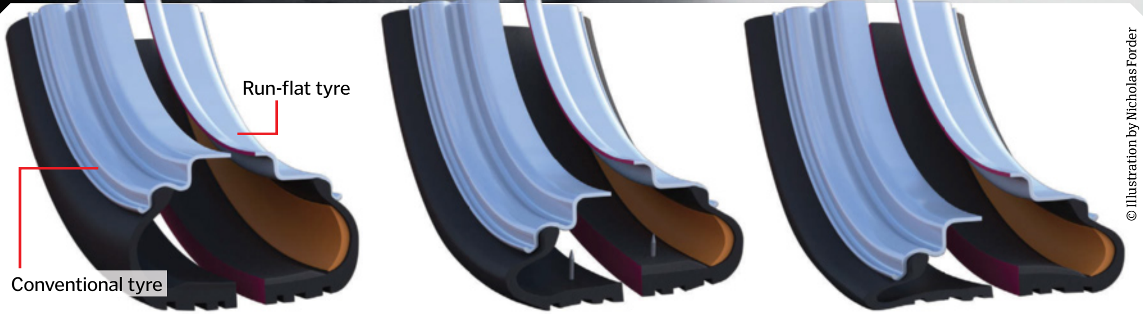
Glass is brittle, meaning that it fractures easily when subjected to stress. When a bullet strikes it, glass can't bend to absorb the energy gradually (in the way you might track your hand back when catching a fast-moving ball). Instead, it shatters, allowing the bullet to pass straight through with almost no loss of momentum.



Bulletproof glass

Technically 'bullet-resistant', since no glass is 100 per cent bulletproof, this material is made by sandwiching layers of an elastic polycarbonate plastic (red) between sheets of toughened glass (blue). When a bullet hits, the outer glass layers still break but the plastic stops them from flying apart. The bullet's energy is dissipated sideways through the multiple layers, which quickly brings it to a stop.





© Illustration by Nicholas Forder

How run-flat tyres work

1 Everyday use
Under normal conditions, both conventional and run-flat tyres maintain constant air pressure, providing a flexible cushion that absorbs shock and increases traction between the vehicle and road.

2 Puncture
After a puncture, conventional tyres drop in pressure immediately. Run-flat tyres have a reinforced sidewall that helps the tyre maintain its shape and stops the wheel rim making contact with the road.

3 Post-puncture
Even when completely depressurised, run-flat tyres can hold out for around 80 kilometres (50 miles), preventing drivers from losing control of their vehicle and allowing them and their cargo to escape danger.

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Official state cars

The high-security vehicles that protect world leaders and royalty

The PM's jacked-up Jag

UK Prime Minister David Cameron is chauffeured to and from engagements in a modified Jaguar XJ Sentinel, driven by a Specialist Protection officer from the Metropolitan Police Service. Bombproof doors, steel and Kevlar armouring, bulletproof glass and a grenade-proof floor keep him safe; the elegant leather and wood veneer interior keeps him feeling suave.

The prime ministerial car is escorted by a fleet of unmarked Range Rovers

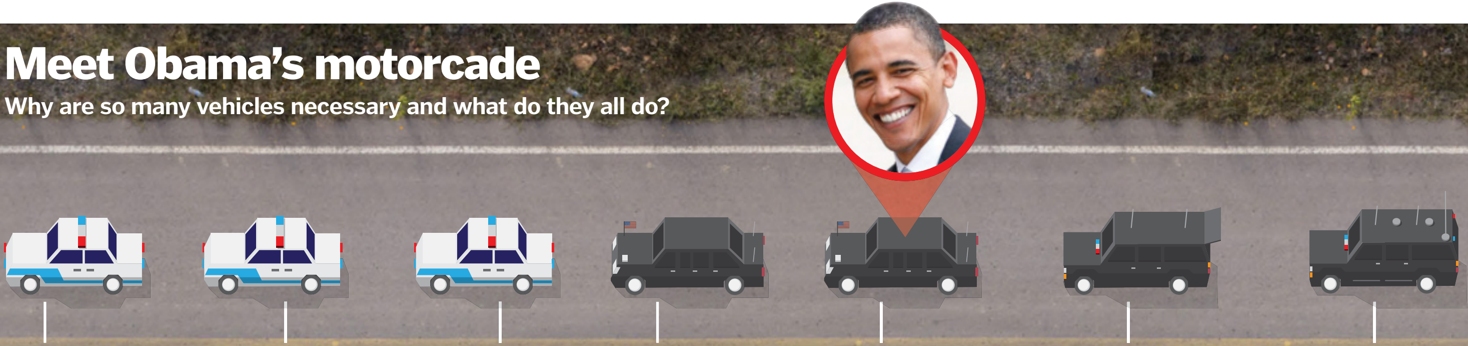
Her Majesty's motorcar

On state occasions, HRH Queen Elizabeth II travels in one of her two bespoke Bentley State Limousines. Gifted to her in 2002 to commemorate her Golden Jubilee, these heavily armoured carriages feature rear-hinged doors for elegant entry and exit, and removable panelling to customise the visibility of their occupants.

The Queen and her head chauffeur had an input on the design of the Bentleys

Meet Obama's motorcade

Why are so many vehicles necessary and what do they all do?



Route car
A local police car sweeps about five minutes ahead of the motorcade, ensuring the route is clear.

Pilot car
Another car runs a minute ahead of the motorcade, validating that the route is clear.

Lead car
A marked police car guides the motorcade.

Spare
This is a decoy vehicle identical to the one the president rides in.

Stagecoach
The president officially rides in this vehicle, although in reality he could be hidden anywhere in the motorcade.

Halfback
This SUV carries the president's Secret Service protection detail.

Codename classified 1
An electronic countermeasures vehicle detects improvised explosive devices or incoming missiles, and sends out jamming signals.

DID YOU KNOW? *On average, an armoured vehicle costs $120,000 (approx £78,000), but can cost as much as $3m (approx £2m)*

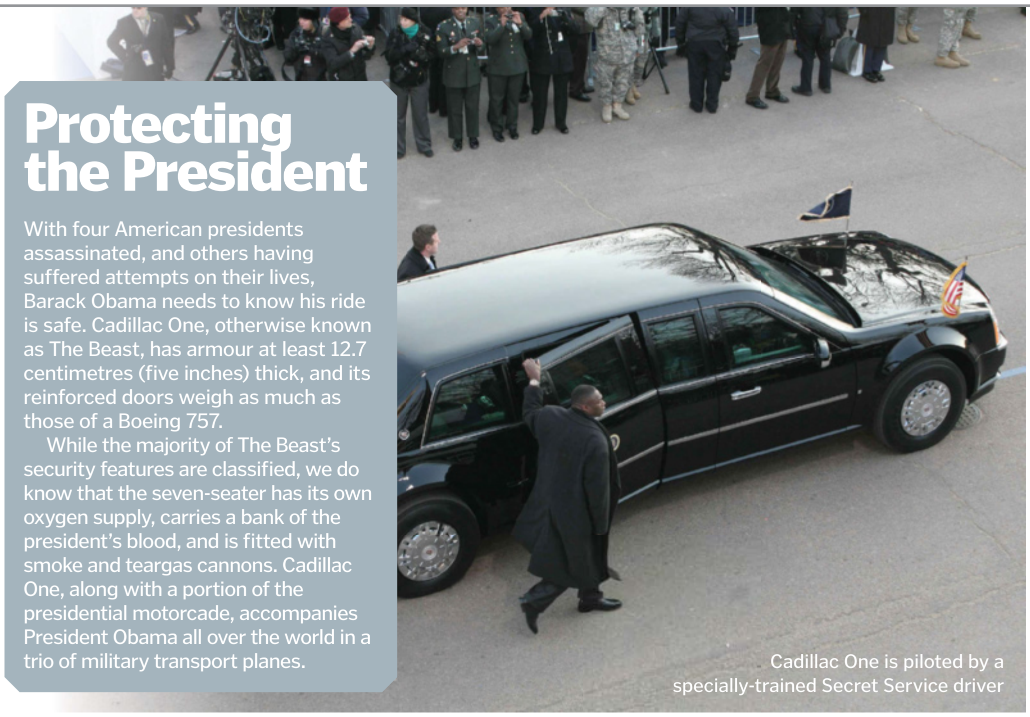
▶ Autera pegs TAC's vehicles as some of the best in the business because they use the lightest weight ballistic steel on the market and strive to find a good balance between extreme armouring and preserving high-end vehicles' original capabilities.

"The armour is only going to be used once in the vehicle's lifetime," explains Kimball, "but the vehicle is used daily, so you want it to perform like a regular vehicle." To ensure that's the case, TAC replaces components of the braking and suspension systems with meatier versions, and reprogrammes the vehicle's computer to eke out the best performance under the new weight conditions.

Nevertheless, armoured vehicles handle differently to their conventional counterparts, making specialised driver training essential. Autera schools private sector, government, military and law enforcement personnel in evasive driving, vehicle counter-ambush and counter-carjacking techniques, and offensive driving. "An essential part of protecting someone in a high-risk environment is an armoured vehicle," he says.

And Autera should know. "We were attacked by a group that was trying to stop our motorcade and either kidnap or assassinate the principal," he recalls of one incident during his time as a driver. "They tried to block our path and they engaged the vehicles with AK-47s. We were able to evade the blocking vehicle and, because we were in armoured vehicles, even though our vehicles took fire, none of the rounds penetrated."

Confidence and composure are critical in such high-stake situations. "You can't inoculate somebody against the response to stress," Autera explains. But training helps drivers to recognise the effects of extreme adrenaline – the narrowing field of vision, muffled hearing, and loss of motor skills – and overcome these to take the necessary actions to move their vehicle and passengers out of danger. "That confidence is essential to survival," he says, "because an armoured vehicle simply buys you time." ▶



Protecting the President

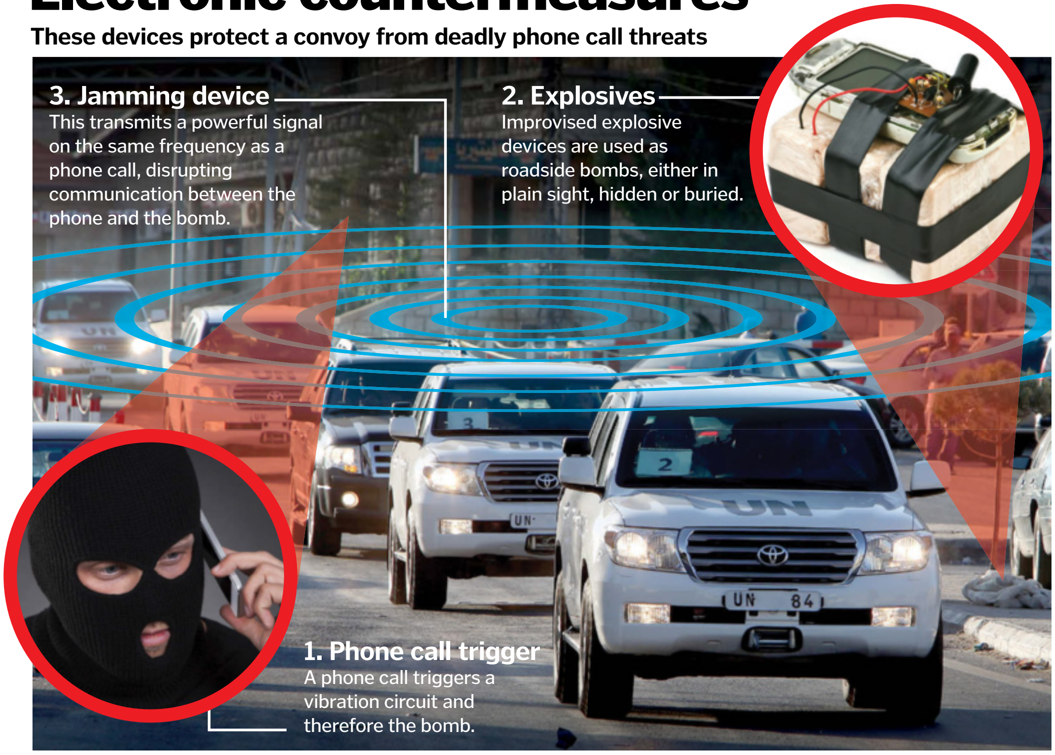
With four American presidents assassinated, and others having suffered attempts on their lives, Barack Obama needs to know his ride is safe. Cadillac One, otherwise known as The Beast, has armour at least 12.7 centimetres (five inches) thick, and its reinforced doors weigh as much as those of a Boeing 757.

While the majority of The Beast's security features are classified, we do know that the seven-seater has its own oxygen supply, carries a bank of the president's blood, and is fitted with smoke and teargas cannons. Cadillac One, along with a portion of the presidential motorcade, accompanies President Obama all over the world in a trio of military transport planes.

Cadillac One is piloted by a specially-trained Secret Service driver

Electronic countermeasures

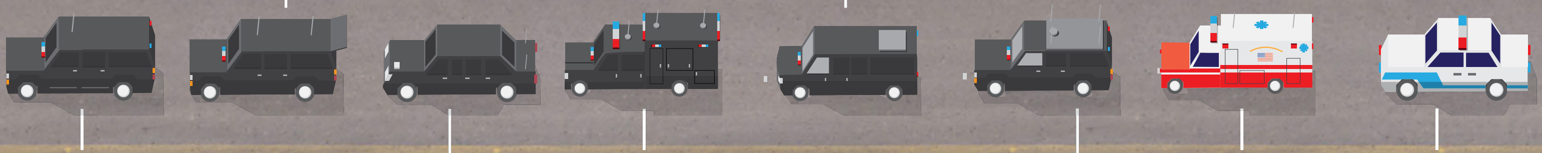
These devices protect a convoy from deadly phone call threats



3. Jamming device
This transmits a powerful signal on the same frequency as a phone call, disrupting communication between the phone and the bomb.

2. Explosives
Improvised explosive devices are used as roadside bombs, either in plain sight, hidden or buried.

1. Phone call trigger
A phone call triggers a vibration circuit and therefore the bomb.



CAT vehicle
The motorcade includes a counterassault team (CAT) to deal with potential attacks.

Press vans
White House reporters are shuttled to presidential engagements.

Support vans
These vehicles transport key White House staff, including a military aide and the presidential doctor.

ID car
This vehicle carries agents who communicate with counter-surveillance teams and intelligence specialists.

Codename classified 2
Scans are conducted for hazardous materials including chemical, biological, and radiological threats.

Roadrunner
A White House Communications Agency van keeps the president in secure contact with the outside world.

Ambulance
Medical aid travels with the motorcade in case of emergency.

Sweepers
Local police bring up the rear to prevent unauthorised vehicles joining the motorcade.

© Rex Features; Corbis; Alamy; Thinkstock

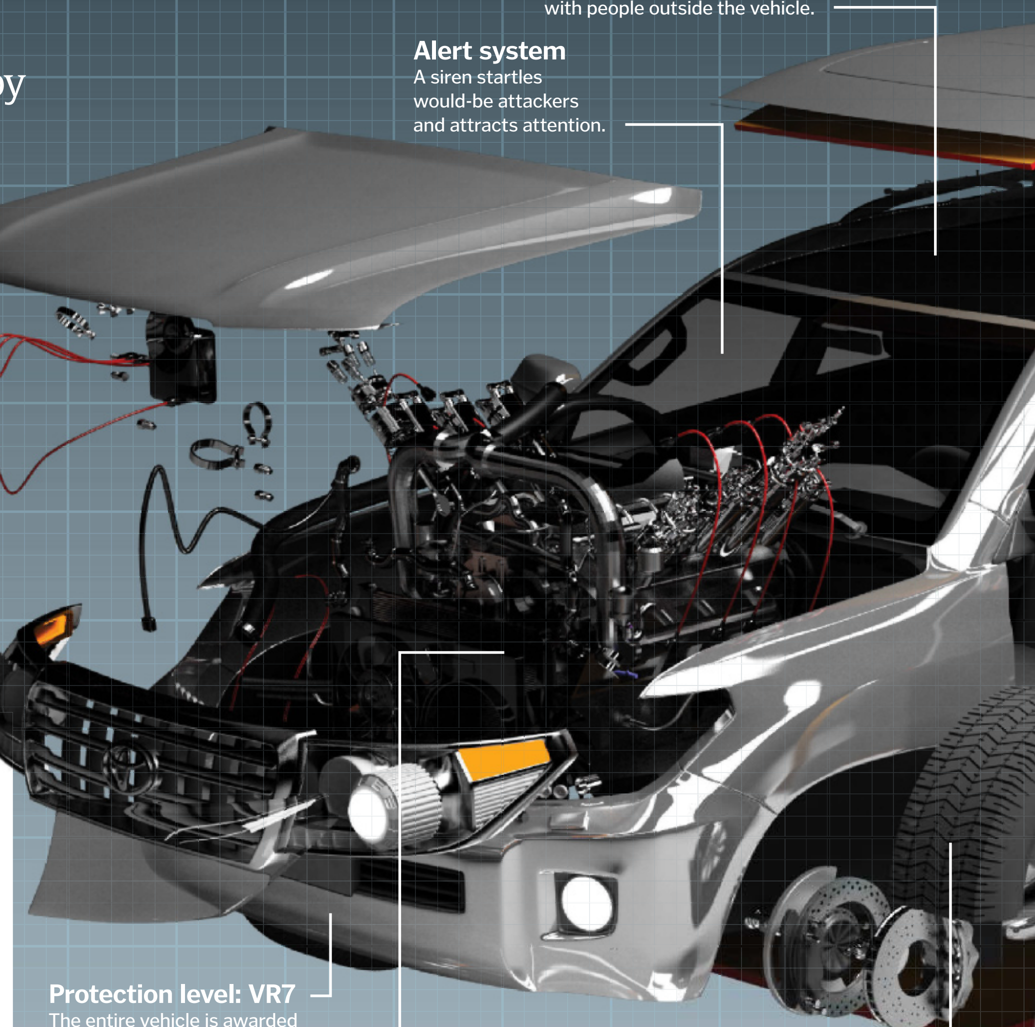
Inside the Jankel Land Cruiser

The armoured SUV 200 favoured by military, NGOs and governments

Industry leader Jankel produces armoured vehicles for police, international security forces and military clients worldwide. Their armoured Toyota Land Cruiser 200 offers extreme blast protection that makes it popular with humanitarian and security organisations operating in hostile environments like warzones.

Its armour is hot-formed, meaning it is heat-moulded to the vehicle from just 31 individual pressed panels (as opposed to the hundreds of pieces used in conventional armouring approaches). This kind of armouring is quicker to complete and the finished product is cheaper, lighter, and more protective than any other alternative.

The entire vehicle goes through extensive live-fire and blast testing, including ballistic rounds fired, hand grenades detonated on its roof, mines detonated under the seats, and 15 kilograms (33 pounds) of TNT detonated two metres (6.6 feet) from the side door. Its performance in these tests earns it a protection certification at one of the highest levels available: VR7.



Secure communication
A PA and intercom system allows occupants to communicate securely with people outside the vehicle.

Alert system
A siren startles would-be attackers and attracts attention.

Protection level: VR7
The entire vehicle is awarded the highest level of blast certification available.

Customisations
Can be custom-fitted with signal jammers, surveillance equipment, vehicle trackers, satellite phones and more.

Run-flat tyres
The Hutchinson run-flat system will hold out for 48 kilometres (30 miles).

Hot-formed armour reduces welding and bolting by 70 per cent

How Texas Armouring Corporation equips their vehicles

1 Gutting

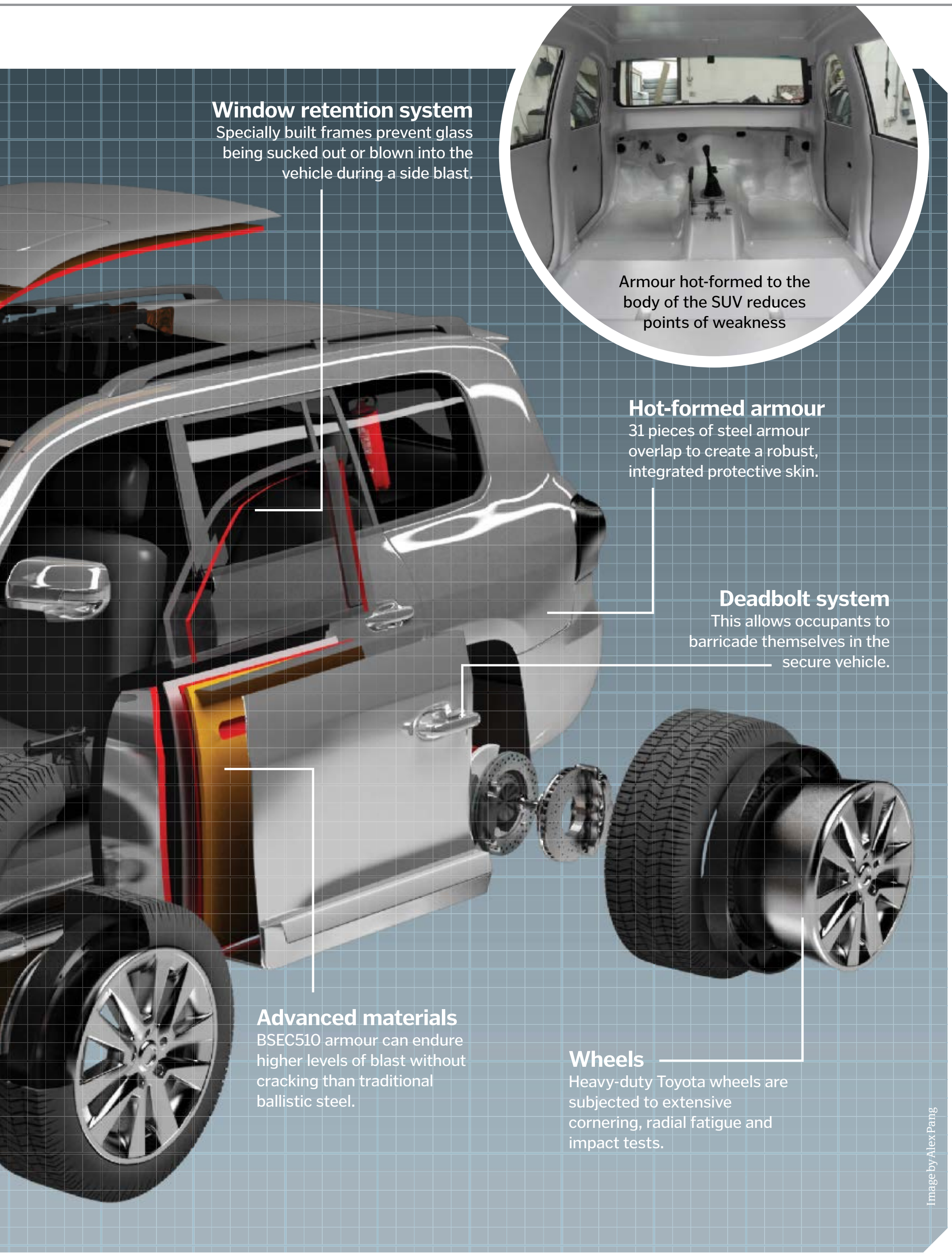
The vehicle is completely stripped. Everything on the inside – seats, floor, roof, carpet, headliners and dashboard – is ripped out, until the vehicle becomes no more than a frame. It is then readyto be lined with armoured materials.

2 Opaque armouring

The body of the vehicle – including doors, floor, roof, fire wall and pillar posts – is lined with advanced protective materials including lightweight composite armour, high-hardened ballistic steel, Kevlar and aramid fibres, and ballistic nylon.

3 Transparent armouring

The windshield, back glass, and door glass are all replaced with five-centimetre (two-inch) thick bulletproof glass. As it is so deep, everything surrounding these windows must be modified to allow the glass to fit.



Window retention system
Specially built frames prevent glass being sucked out or blown into the vehicle during a side blast.

Armour hot-formed to the body of the SUV reduces points of weakness

Hot-formed armour
31 pieces of steel armour overlap to create a robust, integrated protective skin.

Deadbolt system
This allows occupants to barricade themselves in the secure vehicle.

Advanced materials
BSEC510 armour can endure higher levels of blast without cracking than traditional ballistic steel.

Wheels
Heavy-duty Toyota wheels are subjected to extensive cornering, radial fatigue and impact tests.

Image by Alex Pang

This is where those electric shocking door handles come in. "We just want them to be able to get out of a situation, to give them any time they need," stresses Kimball. Unlike the armouring, he sees this sort of addition as an accessory. "That type of thing is fun to talk about, but it's not the life-saving technology," he explains, adding that often clients request things they've seen in Hollywood movies.

Other features that might just buy would-be victims a few extra moments to escape danger include a blinding smokescreen that can be belched out of the back of the car if someone fears they're being followed, and a road tack dispenser that drops spikes onto the road to lacerate the tyres of pursuing vehicles.

Of course, there are more serious additions too. Run-flat tyres – which use either reinforced tyre walls or hardened plastic inserts – can hold out for about 80 kilometres (50 miles) after tyres have been shot, and give a driver the chance to put some solid distance between themselves and their adversaries. A secure deadbolt locking system overrides the automatic lock release that usually happens when a car gets hit – a feature that professional kidnappers have previously been known to exploit.

Finally, internal parts like the fuel tank are also armoured – but not for the reason you might think. "A lot of times in the movies, they shoot at your fuel tank and it automatically explodes. That just doesn't happen," laughs Kimball. Fuel won't catch fire in the absence of a spark, but enough well placed shots could cause a problematic leak and affect getaway capabilities. Self-sealing foam ensures that this doesn't happen.

"Life is valuable. Protect it," runs the TAC slogan. While they may not yet be able to boast invisibility-cloaking devices – like Mr Bond's in *Die Another Day* – these fully loaded security vehicles give ordinary people priceless peace of mind in areas where the threat of armed violence is ever present.

4 Suspension and braking upgrade

Since added armour can weigh anything from 500 to 750 kilograms (1,100 to 1,650 pounds), the vehicle must be fitted with stiffer suspension springs and more heavy-duty shocks. Brake rotors and pads are replaced with racing car parts, to allow faster stopping.

5 Parts and accessories

The fuel tank, radiator, and computer modules are fitted with armour, run-flat tyres are installed and if the client requested operable windows, the motors for these are installed, as well as any extras like a smokescreen system, road tack dispensers, or shocking door handles.

6 Interior re-install

Workers in the 'trim shop' reshape the original interior to fit the new dimensions and contours of the armoured vehicle, endeavouring to match it as closely as possible to the original, unless the client has requested custom colours, fabrics or seating configurations.

Raleigh's new Roker Race

You can tame the toughest gravel tracks and rule the roads with this radical new carbon speedster

Raleigh has been making bikes for 125 years, successfully establishing itself as a truly iconic bike brand. They are adored around the world by all ages, from pre-school children learning to ride to professional racers looking to dominate the Tour de France. The bikes are not only highly innovative and superbly built; each model also offers great value for money, a focus of the company since it began.

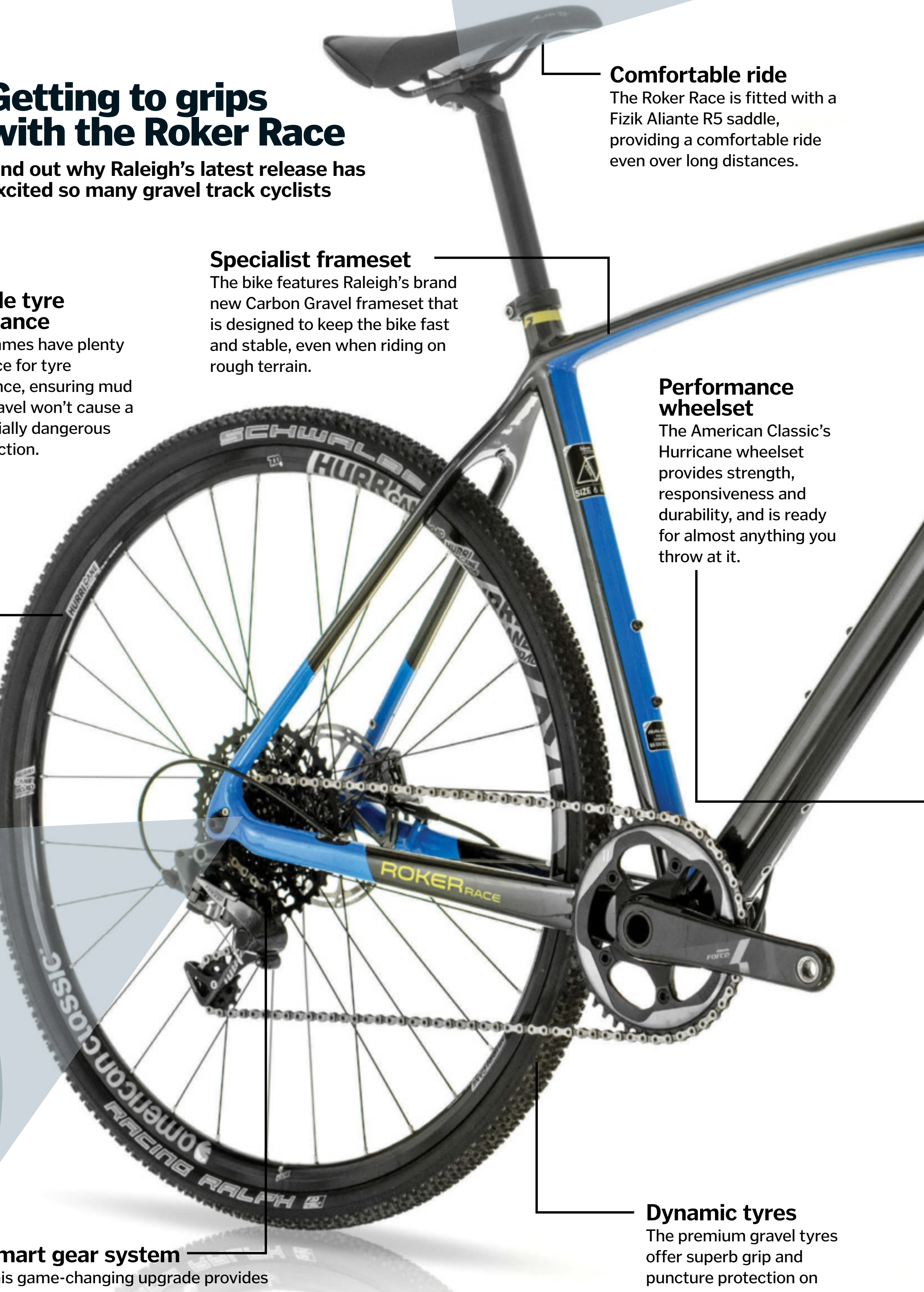
New from Raleigh is the Roker Race, the latest addition to its innovative Gravel Road series. It's perfectly happy on the road but really comes into its own once you get it on a gravel track, effortlessly dealing with the tricky terrain that would grind a traditional road bike to a halt. The attention to detail is second-to-none, taking into account both functionality and comfort in the bike's design.

A revolutionary feature is the SRAM Force Hydraulic brakes. These offer unrivalled braking power and modulation, helping you push the bike to its limits, but not beyond. What's more, the unique clutch system eliminates chain slack, providing for smoother, quieter and more secure chain travel.

For more information on the Roker Race and other bikes in the Gravel Road series, visit **www.raleigh.co.uk**.

Getting to grips with the Roker Race

Find out why Raleigh's latest release has excited so many gravel track cyclists



Comfortable ride
The Roker Race is fitted with a Fizik Aliante R5 saddle, providing a comfortable ride even over long distances.

Specialist frameset
The bike features Raleigh's brand new Carbon Gravel frameset that is designed to keep the bike fast and stable, even when riding on rough terrain.

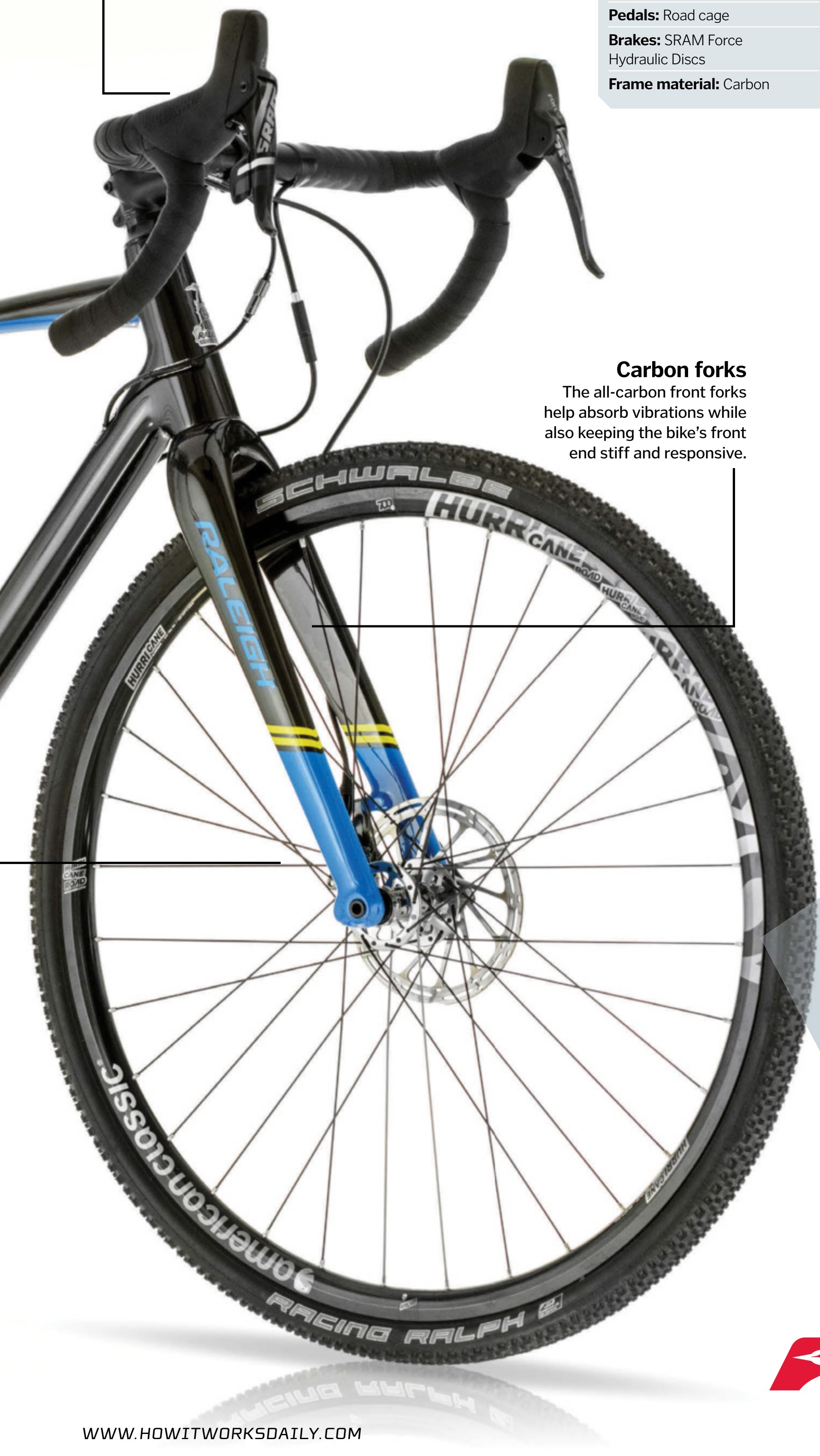
Ample tyre clearance
The frames have plenty of space for tyre clearance, ensuring mud and gravel won't cause a potentially dangerous obstruction.

Performance wheelset
The American Classic's Hurricane wheelset provides strength, responsiveness and durability, and is ready for almost anything you throw at it.

Smart gear system
This game-changing upgrade provides maximum chain control – crucial for multi-terrain riding – while also offering the fastest and quietest shifting available.

Dynamic tyres
The premium gravel tyres offer superb grip and puncture protection on rugged terrain, but also function outstandingly well on tarmac.

DID YOU KNOW? Sir Frank Bowden created Raleigh by buying a small bicycle company in 1887, naming it after the road it was on



Concealed cabling

The cabling is cleverly hidden in the bike's frame, keeping it safe and secure.

Carbon forks

The all-carbon front forks help absorb vibrations while also keeping the bike's front end stiff and responsive.

The statistics…

Weight: 8.1kg (17.9lb)

Wheel size: 700C

Pedals: Road cage

Brakes: SRAM Force Hydraulic Discs

Frame material: Carbon

The Gravel Road series

When Raleigh launched the Maverick in 2015, it was thought it would be a welcome addition to their current road range, filling a niche and giving riders an all road option. However, it soon emerged as their go-to bike for everyday riding. When it came to redesigning the endurance road bike range, Raleigh decided that the best all round machine for British conditions was a gravel road bike, and the new series was born.

Powerful disc brakes and increased tyre clearance were added to the comfortable riding position of Raleigh's Endurance range, making them the most versatile road bikes it has ever built. Whether you're on gravel, country lanes or main roads, these bikes are fast and comfortable enough to ride all day. Large volume tyres have also been added to provide a great balance between grip on the dirt and speed on the road, and the wide range gears make the bikes fast enough for the road but also compatible with steep hills.

Complementing the steel Maverick range are four aluminium Mustangs and the ultimate gravel road bike, the Roker Race.

All of the bikes in the Gravel Road range will tackle the toughest terrain and come out on top

How cars can see round corners

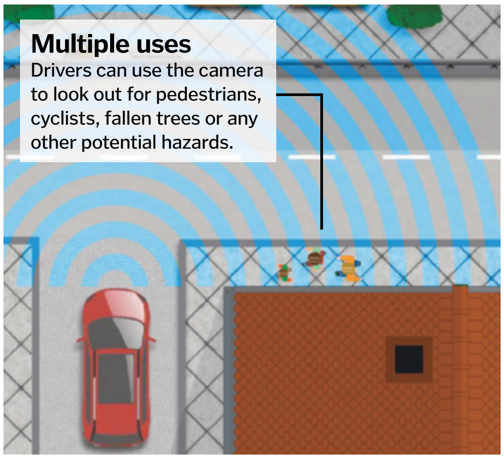
Ford's new camera tech could reduce accidents at blind junctions

For anyone behind the wheel of a car, pulling out at a junction can be fraught with danger. Until now, the only practical method for drivers has been to lean forward and desperately crane their necks in the hope of spotting oncoming traffic, a speeding cyclist or a passing pedestrian.

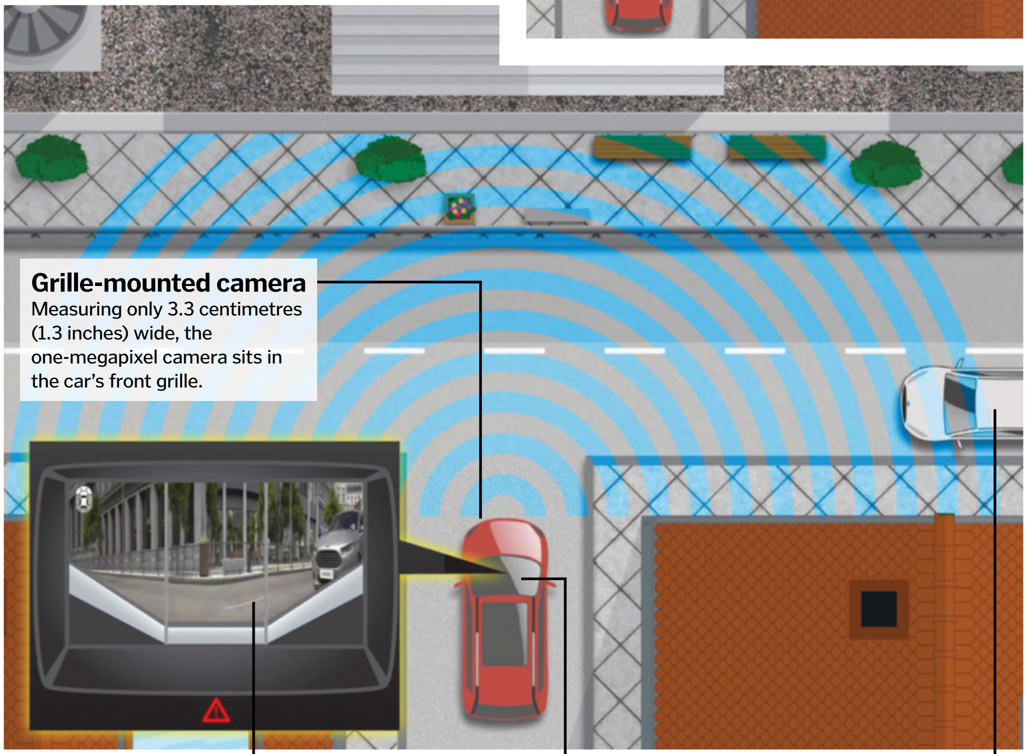
However, Ford's new system could change that. The Front Split View Camera sits in the front grille and feeds a real-time, 180-degree view – from left to right – onto a monitor inside the vehicle. The driver just has to push a button to bring up the panoramic one-megapixel picture of their surroundings onto the touch screen display console. The camera even has its own jet washer to keep the lens clean, which turns on automatically whenever the windscreen wipers are activated.

The Front Split View Camera is only currently available as an option on the Ford S-MAX and Galaxy, but is hoped to be compatible with the majority of Fords by 2020.

Motorists will no longer need to take risks by edging out blindly



Multiple uses
Drivers can use the camera to look out for pedestrians, cyclists, fallen trees or any other potential hazards.



Grille-mounted camera
Measuring only 3.3 centimetres (1.3 inches) wide, the one-megapixel camera sits in the car's front grille.

Tri-panel display
The 20-centimetre (eight-inch) touch screen inside the car clearly shows the oncoming traffic from both directions.

Simple activation
Instead of awkwardly craning their neck to check the junction, the driver simply pushes the camera button on the centre console.

180-degree view
The 180-degree view of traffic reduces the risk of accidents, which are common at junctions with restricted views.

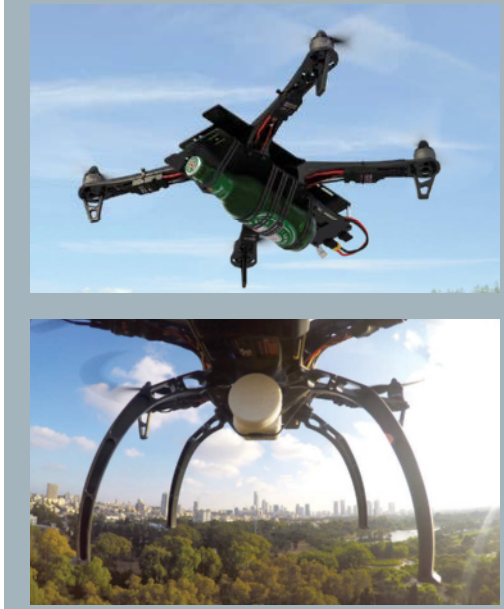
Personal delivery drones

The Flytrex Sky can transport small items to your friends and family

Flytrex is the world's first cloud-connected delivery drone. Capable of transporting packages weighing up to one kilogram (2.2 pounds), the Flytrex Sky is also fitted with a 3G module, allowing it to maintain an internet connection throughout its flight. To pilot the Sky manually, you can connect it to a wide range of apps available on both iOS and Android devices.

If you feel like relinquishing control, this clever quadcopter also features an autopilot system. In order to transport a package autonomously from A to B, it relies upon GPS (global positioning system) to pinpoint its exact location. This works like any GPS-enabled device – by receiving radio signals from satellites. There are about 30 satellites orbiting Earth and each one transmits information about its position and current time. Based on this, the drone can work out exactly where it is and adjust its course accordingly.

When the drone reaches its destination, the recipient can either let the Sky land by itself, or take over manual control to help guide it down to the ground.



To pilot the Sky you can connect it to a range of apps

© Ford

DID YOU KNOW? As outside air passes through the engine's compressors it is heated to over 200°C (392°F), killing any bacteria

Cabin air systems

Find out how air is circulated to hundreds of passengers

The cabin is filled with a 50/50 mix of outside air and re-circulated air

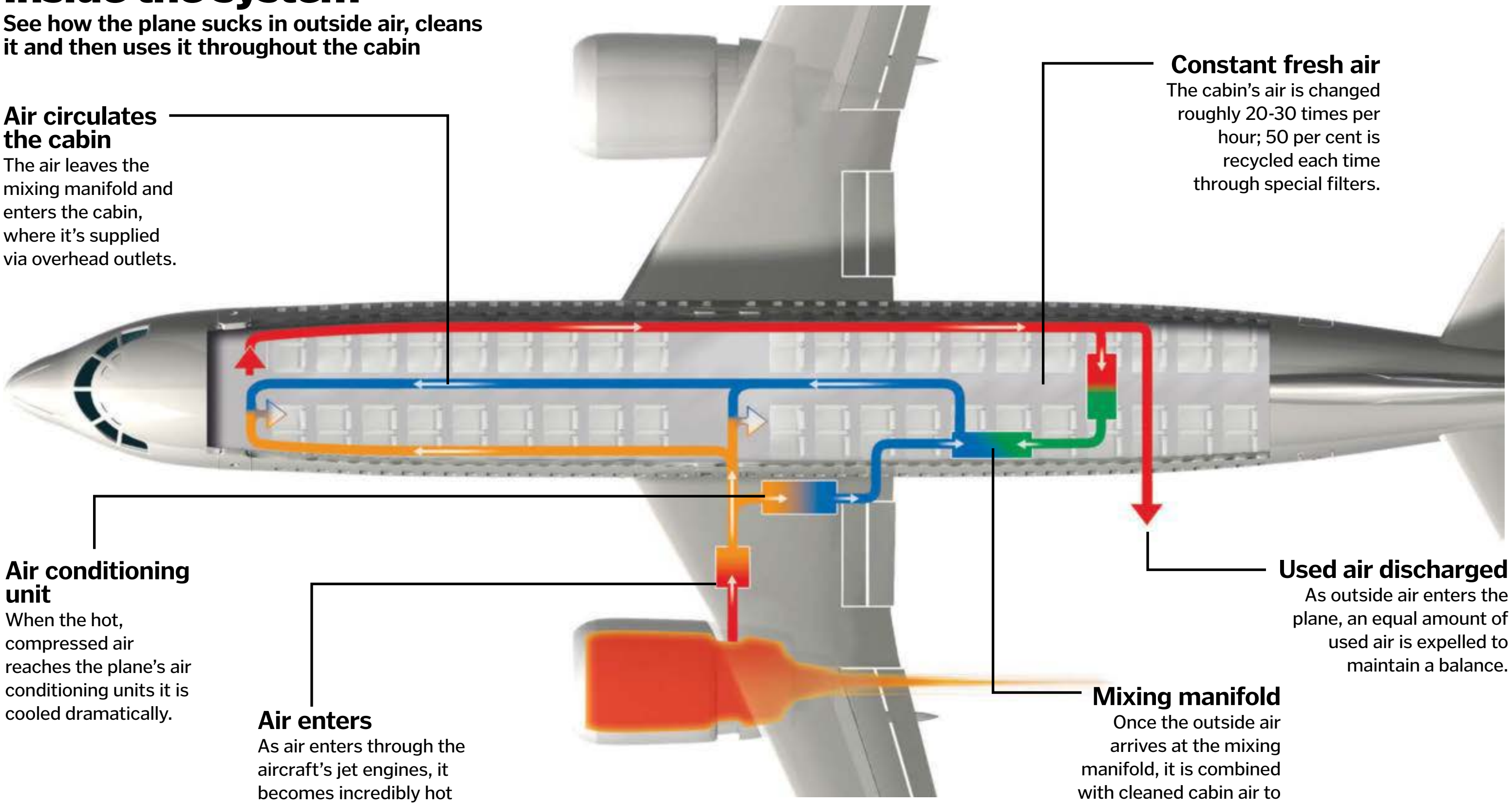
At 12,000 metres (39,000 feet), oxygen pressure is so low that even breathing pure oxygen doesn't transfer enough into your blood. This is why all airliner cabins are pressurised, and need an air supply pumped into them to maintain our most vital life process. If the cabin were to depressurise at this altitude, you'd have approximately 15 seconds to get your oxygen mask on before losing consciousness. The cargo hold is also pressurised to prevent items within passengers' luggage leaking, expanding or bursting.

In a standard commercial air recirculation system, the air that's pumped out is composed of 50 per cent outside air and 50 per cent re-circulated air. The recycled air isn't simply pumped back around the cabin; it goes through a complex cleaning process to remove bacteria, fungi, dust, fibres and odours. This 50/50 mix ensures that the chance of germs spreading is kept very low while also guaranteeing optimal fuel economy for the plane.

The outside component of this mixture is provided by the engines, which take in some of the surrounding air as they fly and compress it. This compression heats the air, so it is cooled and then filtered before being mixed with the recycled cabin supply. Sensors regulate the rate at which outside air is added to the cabin in order to maintain optimum air pressure inside the plane, allowing passengers and crew to breathe easy. ⚙

Inside the system

See how the plane sucks in outside air, cleans it and then uses it throughout the cabin



Air circulates the cabin
The air leaves the mixing manifold and enters the cabin, where it's supplied via overhead outlets.

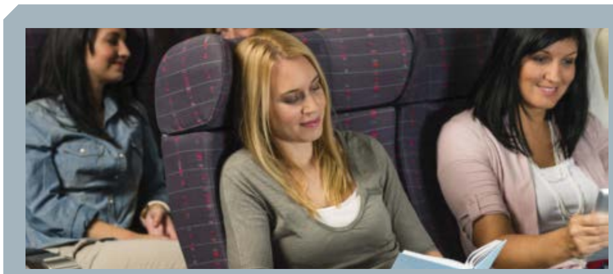
Constant fresh air
The cabin's air is changed roughly 20-30 times per hour; 50 per cent is recycled each time through special filters.

Air conditioning unit
When the hot, compressed air reaches the plane's air conditioning units it is cooled dramatically.

Air enters
As air enters through the aircraft's jet engines, it becomes incredibly hot as it is pressurised.

Mixing manifold
Once the outside air arrives at the mixing manifold, it is combined with cleaned cabin air to produce a 50/50 mix.

Used air discharged
As outside air enters the plane, an equal amount of used air is expelled to maintain a balance.


A plane's air filters are very effective at trapping bacteria and viruses, stopping them from continually circulating the cabin

The truth about air inside planes

People dread flying for a number of different reasons, whether it's a fear of confined spaces or potential disasters. A surprisingly common aspect of flying that makes people nervous is the thought of getting ill, but is cabin air as rancid as people think? Thankfully, the answer is no. Recent studies have shown that a crowded airplane is no more germ-filled than any other typical enclosed space; they are actually more likely to be cleaner. This is partly due to the underfloor, high-energy particulate air (HEPA) filters, which are said to be of hospital quality by their manufacturers. Boeing claim that as much as 99.9 per cent of airborne microbes are captured and removed from the air on their aircraft, and that the air is replaced much more frequently than in an office, classroom or cinema.

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Skidding is more likely in wet weather, or when tyres are underinflated

Traction control

How this clever system prevents wheel spin

It may look cool in the latest James Bond film, but wheel spin can be very hazardous, potentially reducing your ability to accelerate and causing loss of control. To combat this dangerous problem, Buick designed the system of traction control, which first featured in its production cars in 1971.

Modern traction control systems use sensors to constantly measure wheel speed, which are part of the car's anti-lock braking system (ABS). This allows it to immediately recognise when one of the wheels is spinning faster than the others – a sign of traction loss – and reduce the power of the spinning wheel until it matches the others. This works to straighten the car out if it has started hydroplaning on water, or skidding on a slippery surface.

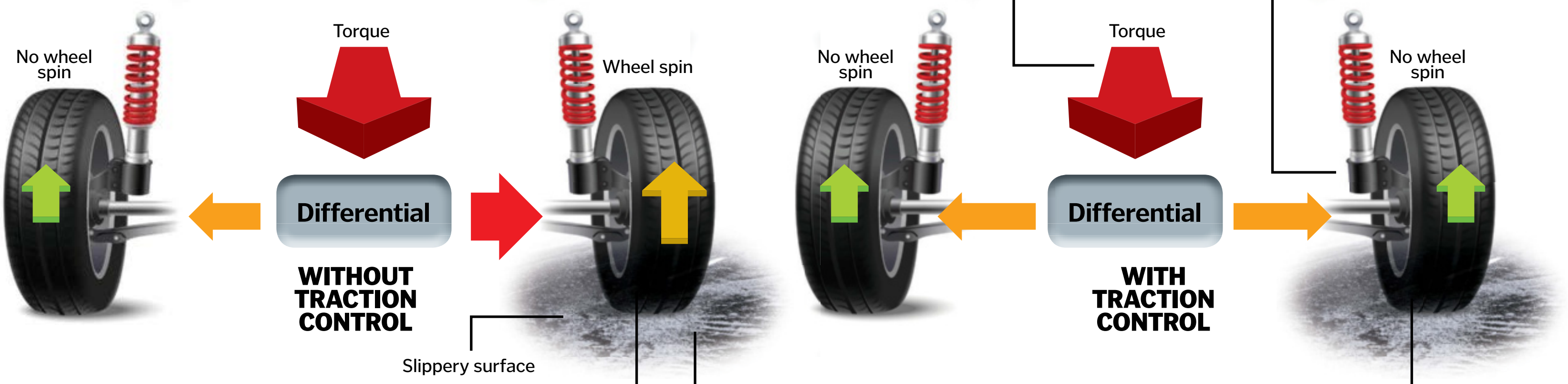
Traction control may sound like the perfect system, but there are times when it doesn't work. Most traction control systems fail to function on ice, because when two or more wheels are struggling to gain traction, the system can get confused and actually make things worse. Having said that, there are very few occasions where you want to turn traction control off: only when you are stuck in snow or plan on racing! ✱

Traction in action

Find out how this system stops your wheels from spinning out of control

Advanced traction control
Some four-wheel drives have more sophisticated systems that control the amount of power fed to each wheel.

Pumping the brakes
Essentially the reverse of ABS, traction control slows the wheel down by using a pumping action on the wheel's brake.



Loss of traction
When a wheel accelerates over a wet or loose surface it can cause it to spin faster than the adjacent wheel, sending the car off course.

Not all-terrain
Traction control is not effective in icy or snowy conditions. Sometimes wheelspin may actually help you get unstuck from the snow.

Equal wheel speeds
Once both wheels are spinning at the same speed and have equal torque, there is less risk of losing control.

Porsche goes electric

This ultra-fast concept car can read your emotions

Porsche is taking on the electric car maker Tesla and its celebrated Model S with an all-electric, 600 brake horsepower beast dubbed 'Mission E'. Although it's only a concept at the moment, Porsche plans on putting it into production, much like they did with the 918 Hybrid concept in 2013. This four-seat sports car is billed to go from 0 to 100 kilometres (62 miles) per hour in 3.5 seconds without a single drop of petrol,and can recharge in 15 minutes.

Among its many technical innovations is one particularly eye-catching feature: a camera that remains trained on the driver's face at all times. This enables the curved, 4K dashboard to know exactly what you're looking at, so that it can highlight the specific information while fading the other dials. This eye-tracking camera can also recognise the driver's mood and displays an emoticon that can be shared on social media.

Porsche is yet to iron out the final details; all they're interested in for now is wowing car enthusiasts with the possibilities that the latest technology brings. We will have to wait a few more years to find out the answer to the big question: is this the best electric car yet? ✱

Porsche's Mission E is only 1.3m (4.3ft) tall, but packs in four full-sized seats and two luggage compartments

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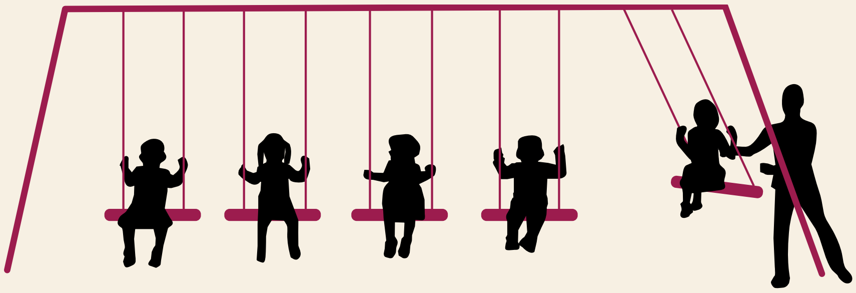

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BACK TO LIFE

THE SCIENTIFIC SECRETS BEHIND THE GREATEST COMEBACK EVER

DID YOU KNOW? *The 39,000-year-old brain of Yuka the young mammoth is almost intact – a unique and exciting find*

The idea of bringing long lost animals back from the dead might sound like a far off dream, but advances in genetic engineering are bringing de-extinction closer to reality. At the TEDxDeExtinction event in 2013, the non-profit organisation Revive & Restore partnered with the National Geographic Society to highlight the progress being made in this cutting-edge field. In a series of talks and articles, they revealed the real science behind the fantasy.

Researchers across the globe are examining different methods of de-extinction, and some teams are making real progress towards the ultimate goal of bringing extinct animals back to life. In fact, in 2003, the impossible was achieved – albeit briefly. A Pyrenean ibex was cloned using a frozen skin sample, and it survived for a few minutes after birth, becoming the first animal ever to have defied extinction. This incredible feat has not yet been replicated, and whether it will be able to produce healthy animals is still unknown, but it marked a huge leap forward for de-extinction science.

Cloning is fraught with challenges – even clones of living species struggle with a pattern of birth defects and health problems – but fortunately, it is not the only way to revive lost species. Genome sequencing technology and genetic engineering techniques mean that researchers are now in a position to start editing animal genetics, potentially allowing them to rebuild the genomes of extinct animals. At least eight extinct species, including the woolly mammoth, have now had their genomes fully or partially sequenced, and using the genomes from living animals as a map, scientists can pinpoint the locations of different genes.

It is already possible to put genes from one animal into another – this is done routinely in medical research – so researchers are working to see whether they can bring genetic traits out of extinction by inserting them into the genomes of close, living relatives. Researchers are even investigating more traditional methods to bring animals out of extinction. By using selective breeding (choosing to cross-breed animals with specific traits), some teams are hoping to create new animals that look, and behave, like ones that are long-dead.

The body of a young mammoth (known as Yuka) was discovered in Siberia and has been incredibly well-preserved

The idea of de-extinction has been met with a mix of excitement, scepticism, and suspicion. The science fiction version didn't end well, and the reality of de-extinction research is an ethical and technical minefield. For a start, there are some big scientific challenges that still need to be overcome. Cloning and creating hybrid DNA are both possible, but using these techniques to produce living, breathing animals presents a whole set of biological hurdles. Several teams have had problems convincing the embryos to grow, and perfecting the art of raising a de-extinct animal is going to take time.

Many people are worried that this process will be costly, or even dangerous. There are concerns that de-extinct animals could harm ecosystems, or even bring back long-lost pathogens. The ethics of meddling in genetics and evolution is also a subject of much debate, and whether species would thrive, or even survive, in the long-term is a huge unknown.

Advocates of de-extinction research suggest that the advancements in genetics and evolution will be worth the risks and costs. Bringing an extinct species back to life is one of the ultimate scientific challenges, and success would be a game-changing achievement. The technical and biological knowledge gained in the process could have benefits that reach far beyond the field of de-extinction.

Whatever your opinion on de-extinction, there is no need to fear a real-life *Jurassic Park*. Beth Shapiro, an expert on ancient DNA from the University of California, Santa Cruz, and one of the key scientists involved in the de-extinction work, told *Smithsonian* magazine that resurrecting the dinosaurs is "not possible", as we simply don't have enough of their DNA. So, while de-extinction is inching closer to reality, there is a clear limit on what it will be able to achieve.

DNA is fragile, and the longer an animal has been dead, the harder it is to find well-preserved genetic information. Without access to the full genome, a species really is lost forever. Genetic editing using the genome of a similar species as a guide could produce hybrid animals that closely resemble the original, but it will not truly bring a species back from the dead. A more realistic future for de-extinction research is the restoration and revival of endangered or recently extinct species. Even with access to modern genetic sequencing techniques, the technology behind de-extinction is still a major challenge to be solved before we can truly bring the dead back to life.

WHY BRING EXTINCT SPECIES BACK?

Scientists at Stanford University have outlined five reasons for and against de-extinction research

For de-extinction

☑ Restoring keystone species, like woolly mammoths and aurochs (the ancestors of domestic cattle), could help to repair ecosystems that are currently unbalanced.

☑ It would fulfil a moral responsibility to undo the damage that we have done to the natural world; many of the species that scientists are trying to revive are extinct because of us.

☑ The research could spark new advances in cloning and genetics technology. This could have far-reaching applications, including helping species that are currently facing extinction.

☑ De-extinction experiments could help to improve our understanding of genetics and evolution – even if attempts are unsuccessful, there is huge potential for new knowledge.

☑ It would be a huge scientific achievement, and an incredible opportunity to study and observe animals that have been lost.

Against de-extinction

☒ The process of restoring extinct species is extremely costly, and the money could be spent on helping to protect living animals in danger across the world.

☒ We do not know whether the animals would still be able to survive in their natural habitat, or what impact they would have on other animals in the ecosystem.

☒ There are concerns about the exploitation and welfare of de-extinct animals. Whether it is right to put a species through the challenging process of de-extinction is still up for debate.

☒ De-extinct animals could potentially be a threat to the health and wellbeing of living species, particularly if they harbour dangerous pathogens.

☒ There is a serious moral question to be answered – is de-extinction 'playing god'? Should we even be attempting it at all?

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On the waiting list

Meet the animals with the best chance of making a comeback

For de-extinction to be even a remote possibility, scientists first need access to well-preserved genetic information. This rules out the dinosaurs and other long-extinct species, but a number of promising projects are underway to revive, restore, or reproduce animals that were lost more recently.

Using a combination of cloning, genome editing, and selective breeding, teams of scientists across the world are getting to work on bringing extinct animals, or at least some of their genes, back to life. These are just six of the projects that are currently underway.

Woolly mammoth

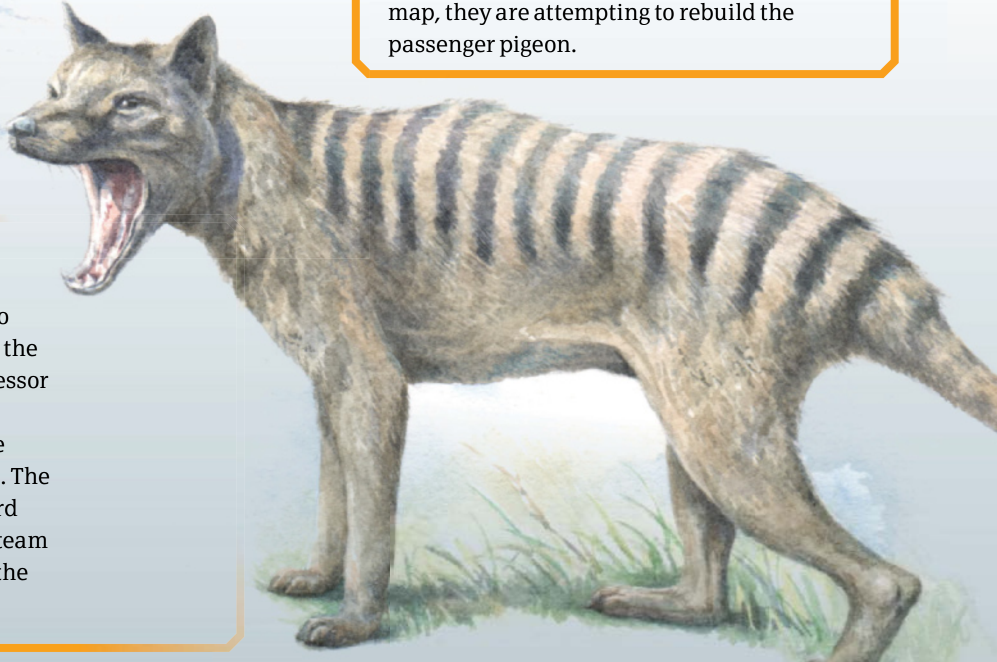
The last of the woolly mammoths died around 4,000 years ago, but thanks to their icy habitat, there are some extremely well-preserved specimens. Dr George Church and his team at Harvard University are trying to revive the species by putting mammoth genes into the DNA of Asian elephant cells.

These modified cells will be reprogrammed to produce stem cells, which will then be used to produce blood cells, hair cells and fat cells. This will allow the effects of the mammoth genes to be studied on a small scale, paving the way to produce a living mammoth/Asian elephant hybrid.

Passenger pigeon

There were once billions of passenger pigeons in North America, accounting for up to 40 per cent of the total bird population, but by the start of the 20th century they were all gone. Professional hunters tore through the population until just one bird was left in captivity in the Cincinnati Zoological Garden. She died in 1914.

In 2002, Dr Beth Shapiro and her team sequenced passenger pigeon DNA, and by 2012 they had obtained samples from over 50 different taxidermy birds. Using the genome of a related bird (the band-tailed pigeon) as a map, they are attempting to rebuild the passenger pigeon.



Thylacine

Thylacines, also known as Tasmanian tigers, were hunted to extinction on the orders of the Tasmanian government, and the last individual died from neglect in Hobart Zoo in 1936. Professor Michael Archer and his team at the University of New South Wales are working to restore thylacines to their native home using DNA from a thylacine pup preserved in alcohol in 1866. The soft tissues of the pup are heavily contaminated, but the hard tissues, like teeth, contain untouched thylacine genes. The team are working on ways to insert this genetic information into the genome of the Tasmanian devil.

DID YOU KNOW? *Other candidate species for de-extinction include the dodo, the New Zealand moa and the woolly rhino*

Gastric-brooding frog

Professor Michael Archer and his team are also working on a project to revive an unusual species of frog. The gastric-brooding frog incubates its eggs in its stomach; it halts digestion, allowing the tadpoles to develop in safety until they are ready to emerge as froglets.

This bizarre Australian species has not been seen in the wild since the early 1980s, but researchers at the University of Newcastle, the University of Melbourne and the University of New South Wales are working together to bring them back. In 2013, they created living embryos by injecting the nucleus of cells from frozen samples into eggs from a related species, the great barred frog. The next step is getting the embryos to grow.

Aurochs

Before cattle were domesticated, wild aurochs were found across the European continent, but by 1627 they had been hunted to extinction. The Tauros Programme, spearheaded by Rewilding Europe, is attempting to recreate this ancient species by cross-breeding primitive domestic cattle.

Specialists in Holland, Spain and Portugal are working with cattle breeds from across Europe to find animals with traits resembling ancient aurochs. By cross-breeding different breeds, they hope to be able to recreate entire herds of these large, hardy cattle.

Heath hen

The heath hen was another victim of human appetite. The birds were once found across North America, but by the late 1800s there were only a few left alive. Their last refuge was the tiny island of Martha's Vineyard in Massachusetts, and despite attempts to save the species, the last individual died in 1932.

In 2015, fragments of the heath hen genome taken from museum samples were compared to the genetic code of a close living relative, the prairie hen. Revive & Restore are now leading a project to investigate whether it will be possible to create hybrid heath hen/prairie hen DNA, and later, to repopulate the island with de-extinct birds.

> *"For de-extinction to be even a remote possibility, scientists first need access to well-preserved genetic information"*

Illustrations by Peter Scott/Art Agency

How to bring animals back from the dead

Different methods of de-extinction have different end results

If there are well-preserved cell samples from the extinct animal, cloning could be an option and this would genuinely bring the species back from the dead. However, if the genetic information is fragmented, it might be better to use genome editing. By inserting selected genes from the extinct animal into the DNA of a close living relative it could be possible to create a hybrid animal, bringing extinct traits back to life. Alternatively, if there is a closely related species still living, selective breeding could be an option. By choosing to cross individuals with the right traits, animals could be bred to resemble their extinct relatives.

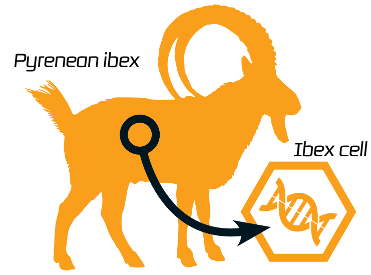
Cloning is the closest that researchers can get to reversing extinction

Cloning

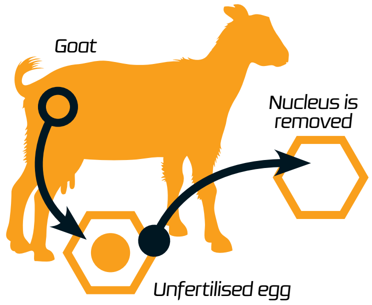
The most complete de-extinction technique is cloning – taking the entire genome of the extinct animal and transferring it into the egg of a close living relative. For this to work, researchers need access to a tissue sample with DNA intact, so recently extinct species like the Pyrenean ibex are the best candidates.

What you'll need

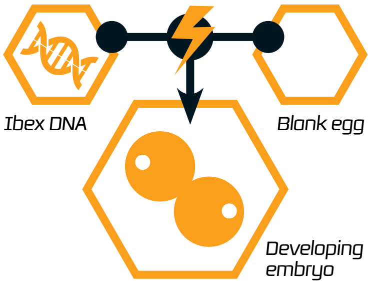
Intact adult cell from extinct species and a donor egg from a similar species (a surrogate mother may also be needed)



1 Cloning requires an intact adult cell from the extinct species. The best quality cells are taken under sterile conditions in the lab when the animal is still alive, but they can sometimes be found in well-preserved remains.



2 An unfertilised egg is taken from a close living relative of the extinct animal, and the nucleus (containing the genetic information) is removed. The egg is then ready to receive the genetic information from the extinct animal.



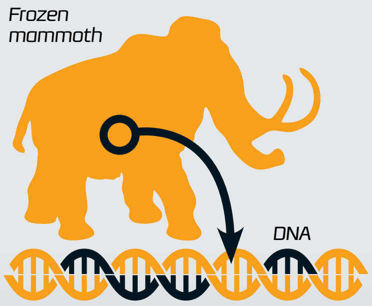
3 DNA is extracted from the ibex cell and injected into the blank egg. A small electric shock is then applied and if this is successful, the fused cell will begin to divide like a normal developing embryo.

Genome editing

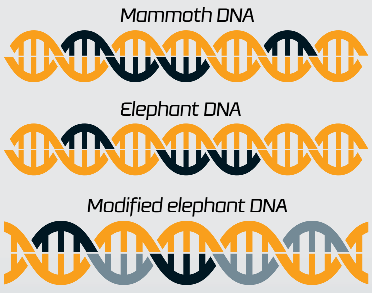
When the complete DNA sequence is unavailable, or cloned embryos do not work, another option is to reverse engineer the extinct species by inserting its genes into the genome of a living relative. This method could work with much older DNA samples, and is being used in projects that aim to revive the passenger pigeon and the woolly mammoth.

What you'll need

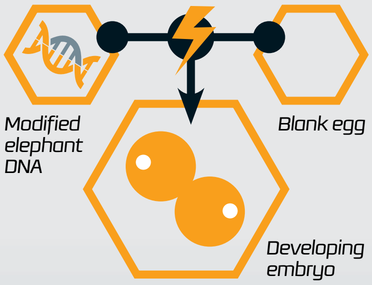
Fragments of DNA from the extinct animal, genome sequence of a related species, donor egg, surrogate mother



1 Genome editing can be done with intact DNA or fragments, which is obtained from samples taken from frozen specimens, taxidermy skin, bones, or other preserved tissues. The DNA is sequenced to reveal the genetic code.



2 The genome of the related species is sequenced, and selected genes are replaced with sequences from the extinct animal. For the woolly mammoth, around 400,000 stretches of Asian elephant DNA are being modified.



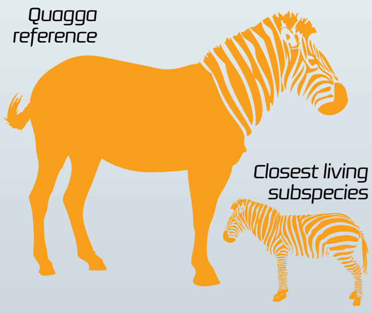
3 As in the cloning method, the genetic information is combined with an empty egg cell from a closely related species. It is shocked to trigger cell division, and the embryo grows using the edited genes as a guide.

Selective breeding

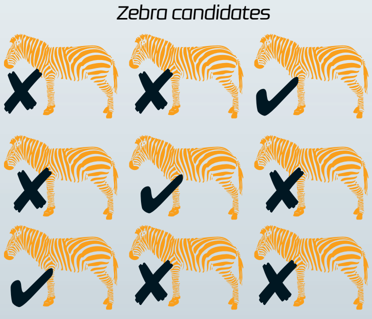
If close relatives of an extinct animal are still living, selective breeding is another possible option. Different animals with traits resembling those of the extinct species are cross-bred for several generations, with the aim of eventually producing an animal similar to the species that was lost. This works best for extinct subspecies, and the idea is already being used to recreate ancient cattle and extinct zebras.

What you'll need

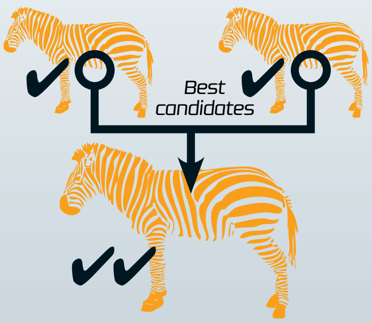
Close living relatives of the extinct species



1 The best candidates for selective breeding are extinct animals that are a subspecies of an animal that is still living. Individuals from the living species will already have traits that resemble those of the extinct subspecies.

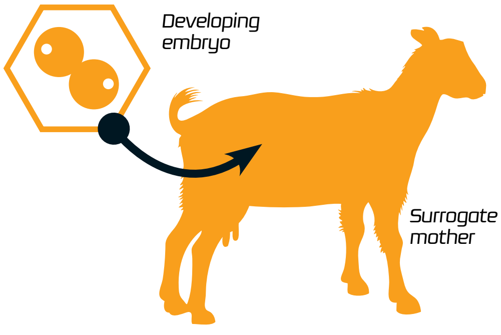


2 The first step is to identify animals that share genetic traits with the extinct species. This can be done by sequencing DNA samples belonging to the extinct animal and comparing them to the genomes of living animals.

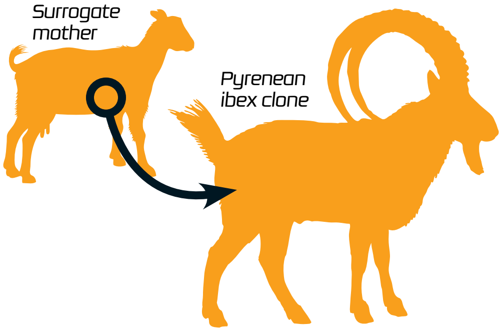


3 A large group of animals is examined. Those that most closely resemble the extinct animal are selected and cross-bred. The offspring that inherit the desired traits are then selected for the next round of breeding.

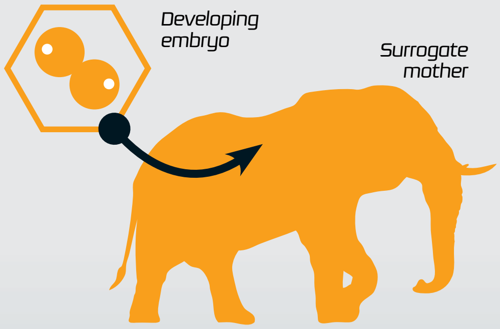
DID YOU KNOW? *Cloning woolly mammoths has been unsuccessful; instead scientists are working on a 'cold-resistant elephant'*



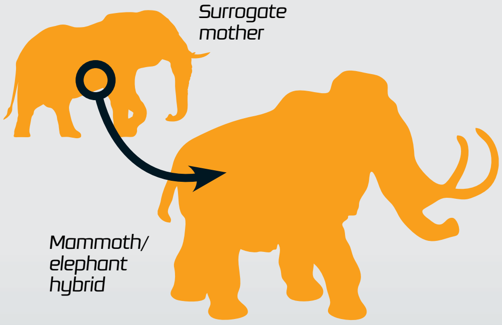
4 If the embryo is a mammal, it must then be transferred into a surrogate mother. This step is extremely challenging, and there is a high chance of failure, particularly if the surrogate is not a good match for the offspring.



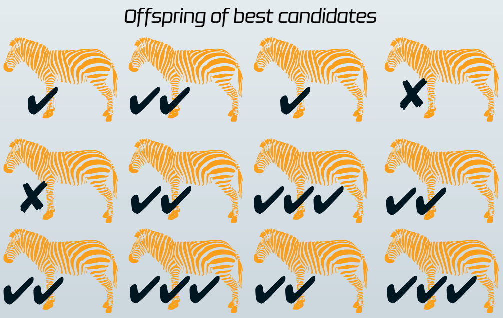
5 The end result is a living clone of an extinct animal, genetically identical to the original. However, there are some major drawbacks of this method, including a high risk of birth defects, and accelerated ageing.



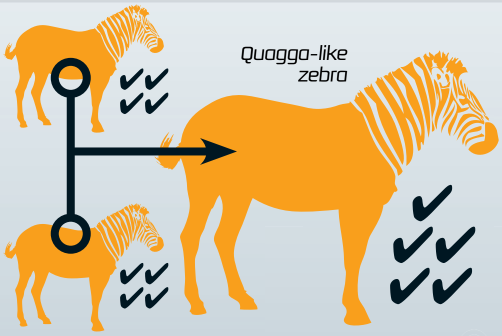
4 The modified egg is then transferred into a surrogate mother, and is allowed to develop to term. With so many changes to the genome, it is difficult to predict whether this unusual kind of pregnancy would be successful.



5 The end result of genome editing will be a hybrid with genetic traits from both the extinct animal and its living relative. By focussing on editing key areas of difference in the genome, researchers hope to recreate something very close to the original.



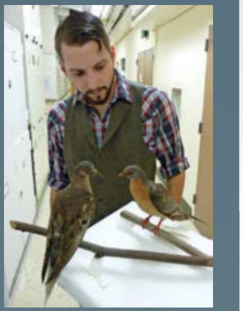
4 After each successive round of breeding, the offspring are examined and scored, and only those with the closest resemblance to the extinct species continue in the programme. Over time, the appearance of each generation gradually changes.



5 This type of projects aims to produce animals that look and behave like extinct species, but are actually genetically distinct. Despite not being identical to the original, they could still help to fill gaps in ecosystems that have been damaged by extinction.

Engineering the passenger pigeon

Ben Novak, lead researcher at Revive & Restore, is passionate about bringing back this North American native



Why did you choose the passenger pigeon?
The passenger pigeon was the flagship project of Revive & Restore and I was brought on for my knowledge of the species and my motivation to make this happen. The passenger pigeon afforded a lot of advantages as a starting candidate – we know a lot about its history and habitat needs, there are hundreds of specimens to work with, and a close living relative to engineer. Humans have 8,000 years of experience working with domesticating pigeons, and the eastern United States' forests have been growing back for 75 years, regenerating their habitat.

What stage are you at in the project?
We are nearing the end of what I've deemed Phase One – our genomic research. We've laid down foundation work for starting Phase Two, when we will work on actually engineering a passenger pigeon. And we now have committed, pledged, future team members for Phase Three – breeding and introducing birds to the wild.

The project has now gained enough information from genomic research, and the field of avian biotech has advanced enough that we can really flesh out the entire project. The one thing our work hinges on is developing the conditions to grow band-tailed pigeon primordial germ cells in the lab. These are the only cells that will produce breeding lines of birds when engineered and to do this we need to be able to breed band-tailed pigeons efficiently in captivity. We need special breeding facilities for this phase. Breeding and germ cell culturing are the two parts of Phase Two that we are seeking funds for currently.

If science were no object and you could choose any species to resurrect, which would it be and why?
Putting my project species aside and disregarding all of the many considerations that bear down on such endeavours, at the top of my list would be the Choiseul Crested Pigeon. It's one of the most spectacular bird species to ever live, and also one of the least known and understood, having been observed only once by Anglican explorers. I'd also like to bring back the Dodo bird; it's the icon of human-caused extinction and another amazing pigeon! Do you see a trend yet? Ultimately, my goal is a future with more life in this world of all kinds, rather than less.

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De-extinction success stories

Reviving the dinosaurs might be an impossible dream, but de-extinction is coming closer to reality

Pyrenean ibex

There were once four subspecies of Spanish ibex, but the last Portuguese ibex died in the late 19th century and by 2000 the last Pyrenean ibex was gone too.

However, researchers had been tracking the last Pyrenean ibex (a 13-year-old female named Celia), and ten months earlier they had preserved some of the skin cells from her left ear and left flank in liquid nitrogen.

Using the preserved skin cells, the team transferred the ibex DNA into the empty eggs of domestic goats. They then cross-bred Spanish ibex and domestic goats to produce hybrid animals that would be capable of carrying these embryos as they developed.

In 2003, 154 cloned embryos were transferred into 44 of these hybrid goats, and seven became pregnant. Only one cloned Pyrenean ibex made it to term.

Unfortunately, the ibex was born with lung abnormalities and died within just a few minutes, but it became the first animal ever to have been brought back from extinction.

The study was published in 2009, but a lack of funding prevented further experiments. However, at TEDxDeExtinction 2013, researcher Dr Alberto Fernandez-Arias told the crowd that the lab had begun testing the skin cells to see whether the cloning effort could start again.

Cloning is extremely challenging, even with recently extinct animals like the Pyrenean ibex

Resurrecting the Pyrenean ibex

1999 Scientists collect skin cells from the ear of a Pyrenean ibex

2000 The same ibex, the last of her kind, is killed by a falling tree in Spain

2003 The skin cells are used to clone a Pyrenean ibex, but it dies quickly

2009 The results of the cloning experiment are published

2013 Scientists start work to test the skin cells for future cloning experiments

DID YOU KNOW? 'Quagga' comes from the Khoikhoi word for zebra and is thought to be onomatopoeic, echoing the animal's call

Quagga

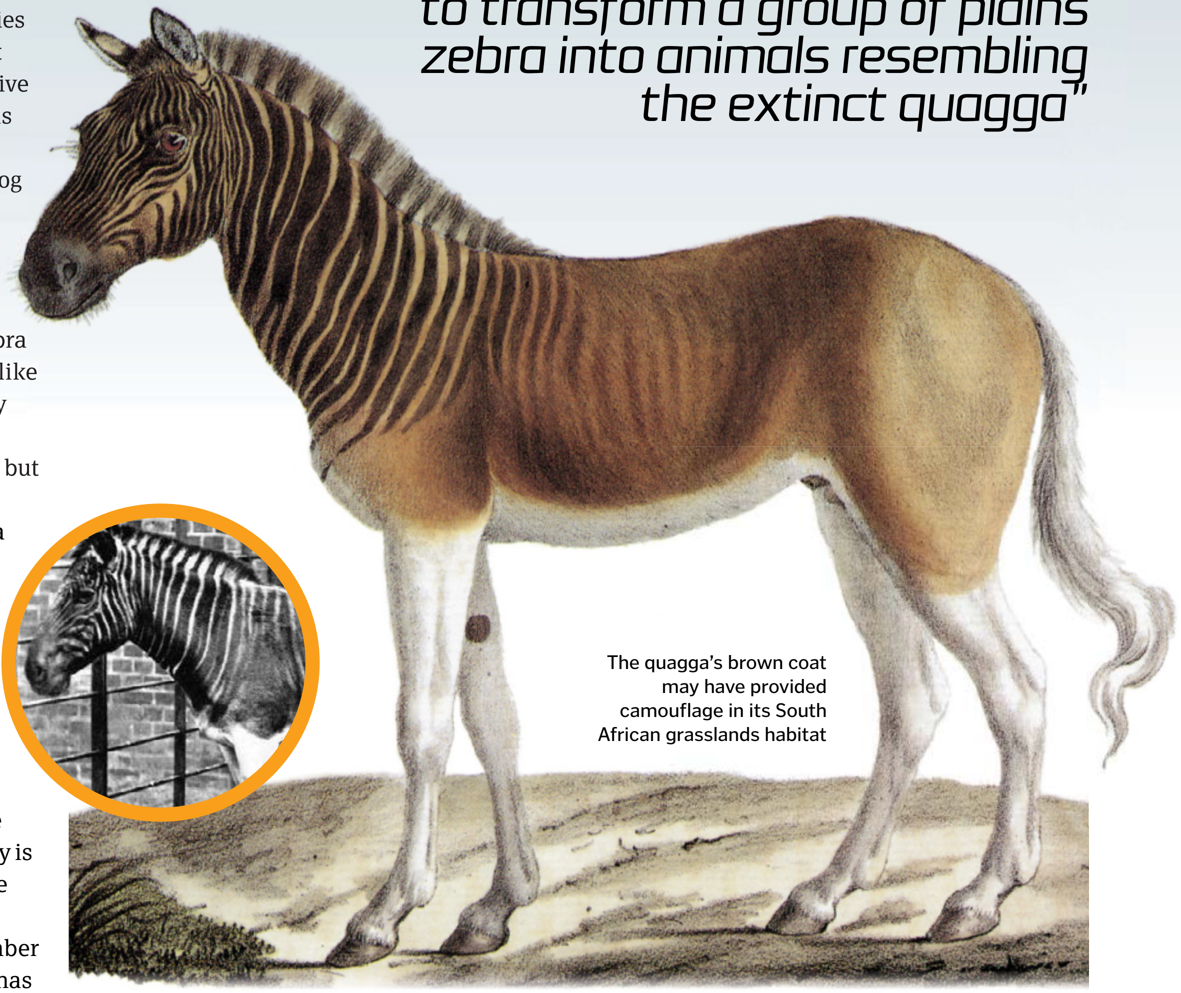
Another realistic approach to bringing species back from extinction is to do something that has been common practice for years – selective breeding. By choosing to crossbreed animals with desirable traits, we have shaped the appearance of over 200 different breeds of dog and have moulded thousands of different domestic animals. Since 1987, The Quagga Project in South Africa has been working to apply this technique to plains zebras.

The quagga was a subspecies of plains zebra with a distinctive brown and white coat. Unlike their familiar black and white relatives, they only had stripes on their heads, necks, and shoulders. They were native to South Africa, but were hunted to extinction to make way for domestic livestock, and the last one died at a zoo in Amsterdam in 1883.

In 1987, a team of researchers began work to transform a group of plains zebra into animals resembling the extinct quagga. Around 2,500 plains zebra were examined, and nine were selected for inclusion in a 're-breeding' programme in an attempt to bring the quagga back.

Since then, each quagga born through the programme has been given a score. The body is divided into five sections, and the stripes are counted and compared. The best ones are chosen for breeding, and over time, the number of stripes on the back and legs of the zebras has been decreasing.

> "A team of researchers began work to transform a group of plains zebra into animals resembling the extinct quagga"



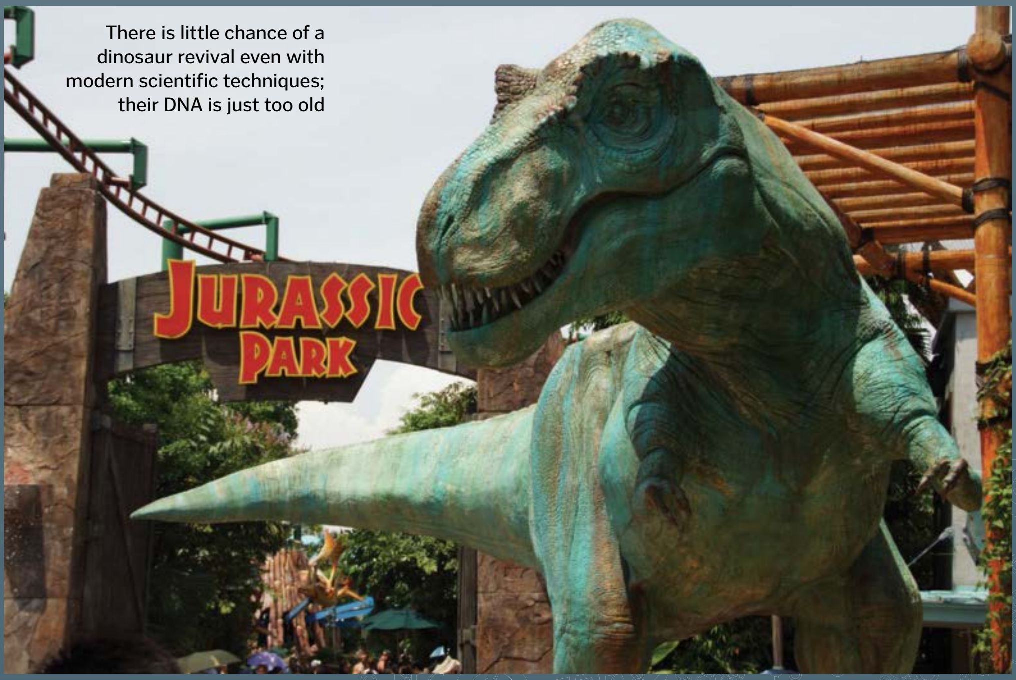
The quagga's brown coat may have provided camouflage in its South African grasslands habitat

Why Jurassic Park will never happen

The *Jurassic Park* media franchise is built around the idea of de-extinction, but the underlying science is full of holes. The scientists in the first film recreated the dinosaurs using DNA recovered from blood-sucking insects that had been preserved in amber. They extracted the fragments' preserved genetic information, sequenced it, and then used frog DNA to fill in the blanks. The completed genetic code was then put into an ostrich or emu egg.

This protocol might sound scientific, but the chances of producing a dinosaur using this method are slim. The first challenge would be finding dinosaur DNA preserved in amber; even insects preserved in amber are rare. In fact, only one blood-filled mosquito has ever been discovered, and it was 46 million years old – nearly 20 million years too young to have fed on a dinosaur.

Even if we could find the right sample, recovering intact dinosaur DNA would be a struggle. DNA is very fragile, and although some scientists claim to have successfully recovered samples from ancient insects preserved in amber, the results have been very difficult to confirm or replicate. The film's choice of a frog as an animal to fill the gaps in the genome is also odd – dinosaurs are much more closely related to birds.



There is little chance of a dinosaur revival even with modern scientific techniques; their DNA is just too old

© Warren Seah / Alamy; Science Photo Library

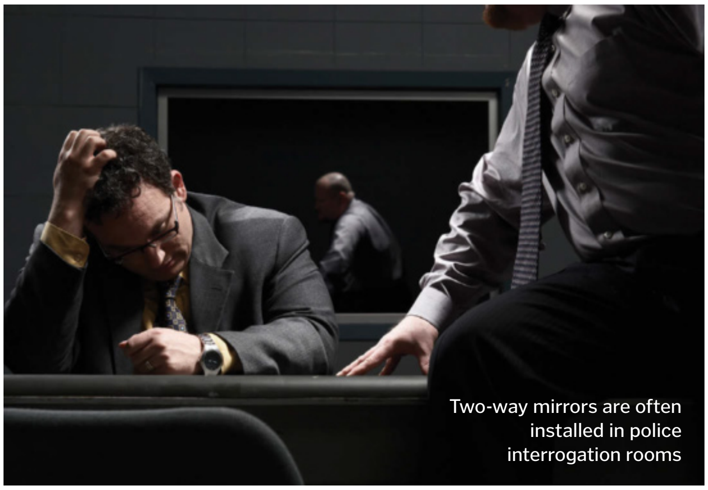
Two-way mirrors

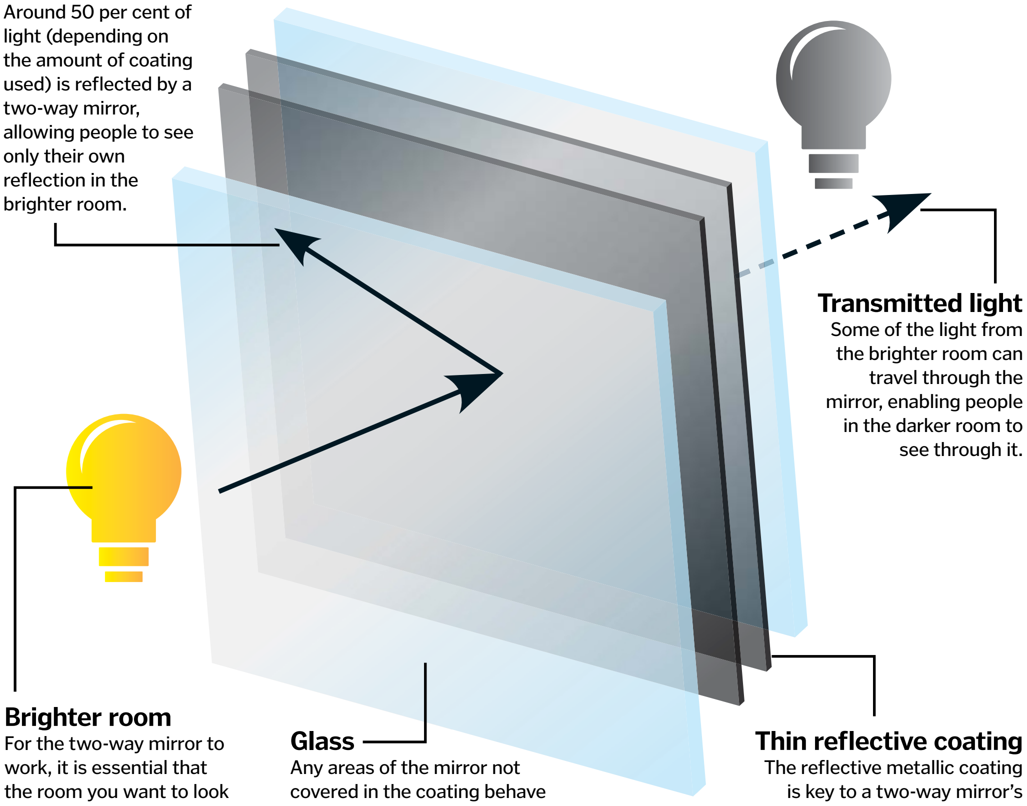
A trick of the light or clever design?

Eyes narrowed, the officer takes a swig of coffee as she watches the interrogation unfold in the next room. The suspect seems to be staring back, but all he can see is his own reflection, such is the magic of a two-way mirror. The secret lies in the design, which differs only slightly from the traditional kind.

Typically, mirrors are composed of a piece of glass covering a layer of metal (usually aluminium). When light passes through the glass and hits the metal it is reflected, which is why you see yourself when you look into it. A two-way mirror also contains this metal coating, but much less of it is used. For example, if just half the mirror's total surface area is covered by reflective molecules, the two-way mirror reflects only half of the light that hits it, meaning the remaining light can pass through to the other side. As long as the room on the other side is darkened, it will be possible to see through the mirror into the brighter room.

There is a way to check whether you're facing a two-way mirror. Place your fingernail against the reflective surface, and if there is a gap between your fingernail and the reflected image, the mirror is genuine. If there's no gap then beware, you could be being watched. ✽


Two-way mirrors are often installed in police interrogation rooms


Reflected light
Around 50 per cent of light (depending on the amount of coating used) is reflected by a two-way mirror, allowing people to see only their own reflection in the brighter room.

Transmitted light
Some of the light from the brighter room can travel through the mirror, enabling people in the darker room to see through it.

Brighter room
For the two-way mirror to work, it is essential that the room you want to look into is brighter than the room you are stood in.

Glass
Any areas of the mirror not covered in the coating behave just like a window, allowing light to pass through.

Thin reflective coating
The reflective metallic coating is key to a two-way mirror's function and is usually made of aluminium.

Odour sprays explained

Do they simply mask smells, or can they actually remove bad aromas?

Products such as odour sprays have often been criticised by scientists for their wrongful claims of destroying smells, when they actually only mask them with a stronger scent. However, modern odour sprays do have some real chemistry behind them, and are perfect for those of us looking for a quick fix to a whiffy problem.

Sprays such as Febreze contain a chemical called cyclodextrin. These molecules have a cage-like structure that means they can trap other molecules within them. Cyclodextrin forms a ring with a hydrophobic (water repelling) centre, enabling it to attract other hydrophobic molecules, such as the molecules causing the unpleasant smell.

At this stage, the bad smelling molecule is still there but is unable to bind to the scent receptors in your nose, so you can't actually smell it. Rather than just being covered by another smell, which is how cheap, masking odour sprays work, the molecules have been effectively neutralised. As an odour spray dries, scented molecules bind to the cyclodextrin at a faster rate, lowering the concentration present in the air and eliminating the odour permanently. ✽

Odour sprays need to have their own strong scent to overcome their odour neutralising properties

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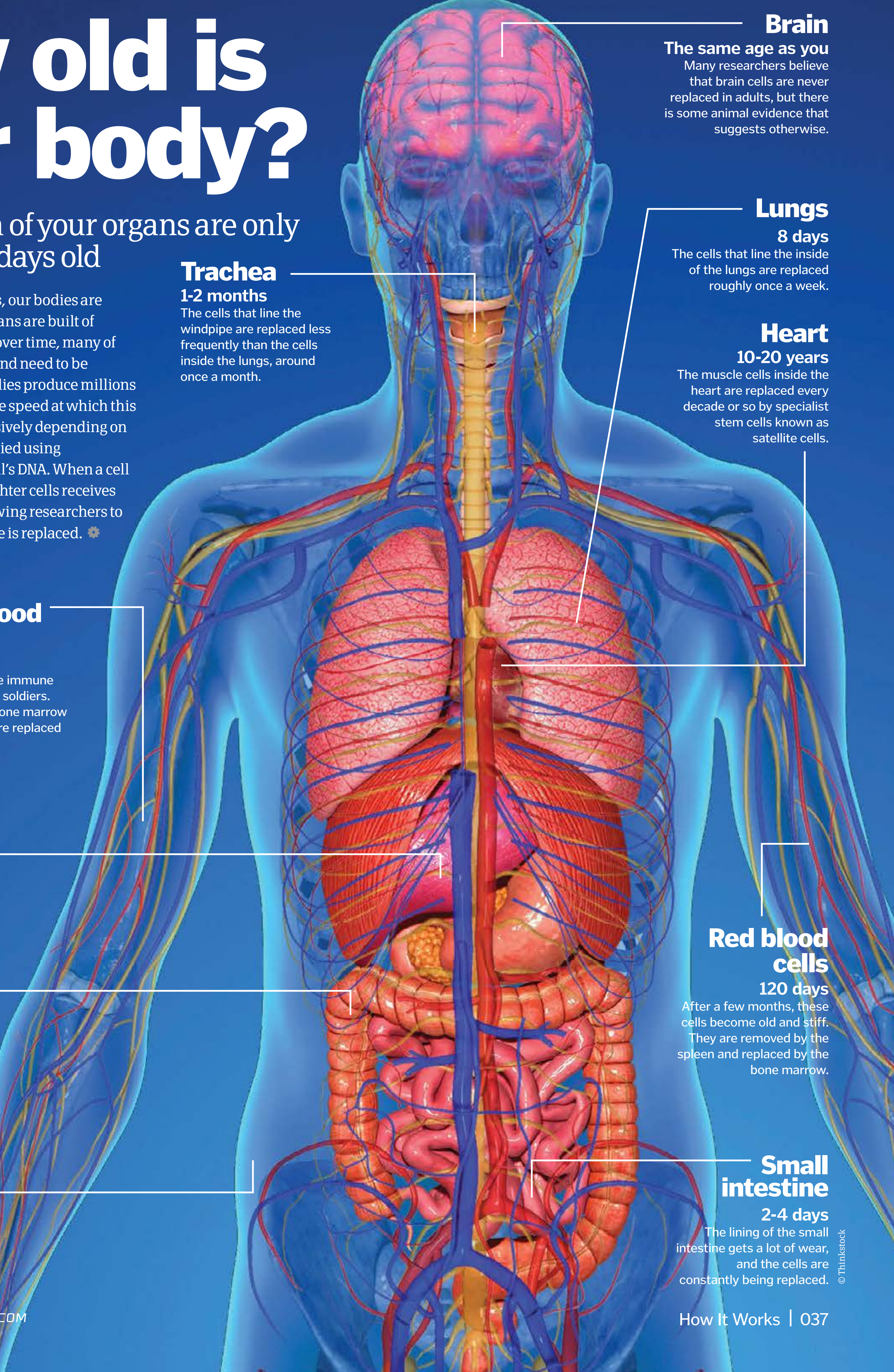
How old is your body?

Discover which of your organs are only weeks or even days old

Like all living organisms, our bodies are made up of cells – humans are built of trillions of them – and over time, many of them become old and worn and need to be replaced. To keep up, our bodies produce millions of new cells every second. The speed at which this process happens varies massively depending on the cell type, and can be studied using techniques to 'mark' each cell's DNA. When a cell divides, each of the two daughter cells receives half of the marked DNA, allowing researchers to track how often each cell type is replaced. ✻



Brain

The same age as you

Many researchers believe that brain cells are never replaced in adults, but there is some animal evidence that suggests otherwise.

Lungs

8 days

The cells that line the inside of the lungs are replaced roughly once a week.

Trachea

1-2 months

The cells that line the windpipe are replaced less frequently than the cells inside the lungs, around once a month.

Heart

10-20 years

The muscle cells inside the heart are replaced every decade or so by specialist stem cells known as satellite cells.

White blood cells

1-5 days

Neutrophils are the immune system's front line soldiers. Stem cells in the bone marrow ensure that they are replaced every few days.

Liver

6-12 months

The liver has an incredible capacity for regeneration, and its cells are replaced once or twice a year.

Red blood cells

120 days

After a few months, these cells become old and stiff. They are removed by the spleen and replaced by the bone marrow.

Large intestine

3-4 days

The cells of the large intestine are constantly being shed into the gut, and are replaced by cells that move upwards from underneath.

Fat

8 years

The number of fat cells in the body does not change much, even when we gain or lose weight.

Small intestine

2-4 days

The lining of the small intestine gets a lot of wear, and the cells are constantly being replaced.

© Thinkstock

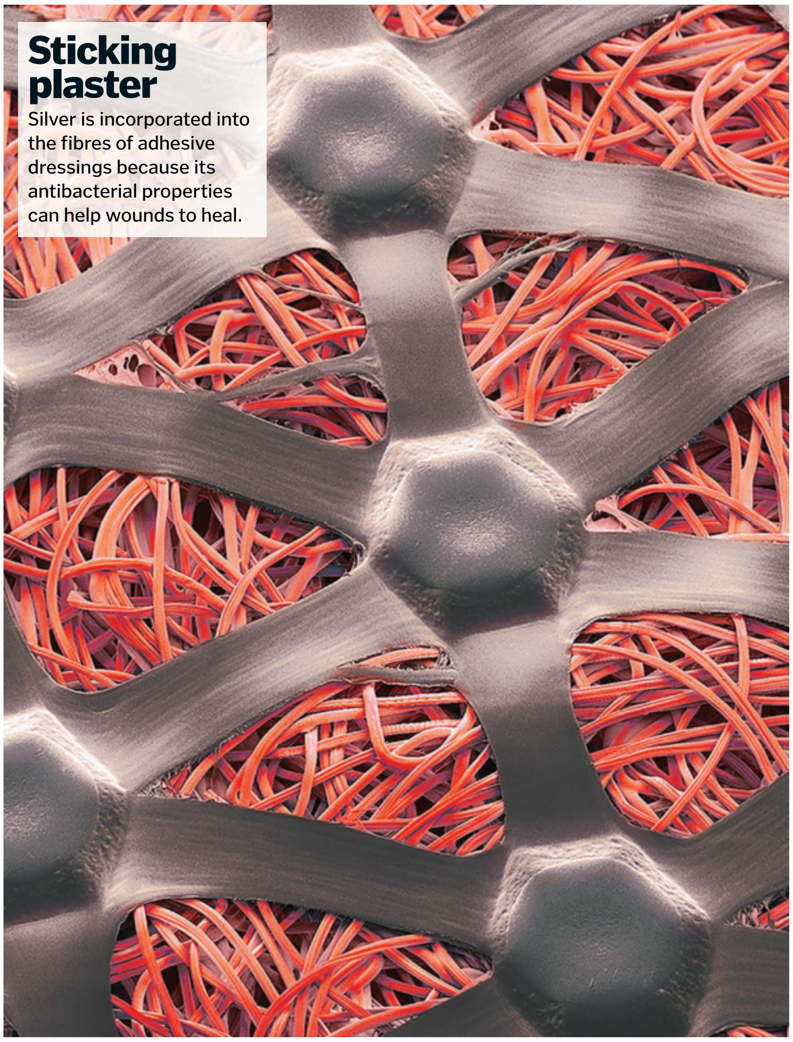
Science under the microscope

Incredible close-up images uncover the hidden world around us

Taking a closer look at even the most ordinary of objects can reveal beauty you never knew was there. To help expose some of these breath-taking secrets, the Royal Photographic Society challenged the general public to photograph whatever they could get their hands on, all in the name of science. Their 2015 International Images For Science competition received submissions from scientists, students and even young schoolchildren, showcasing stunning photography of sub-atomic particles, distant galaxies and everything in between. Here is a just a selection of the amazing entries.

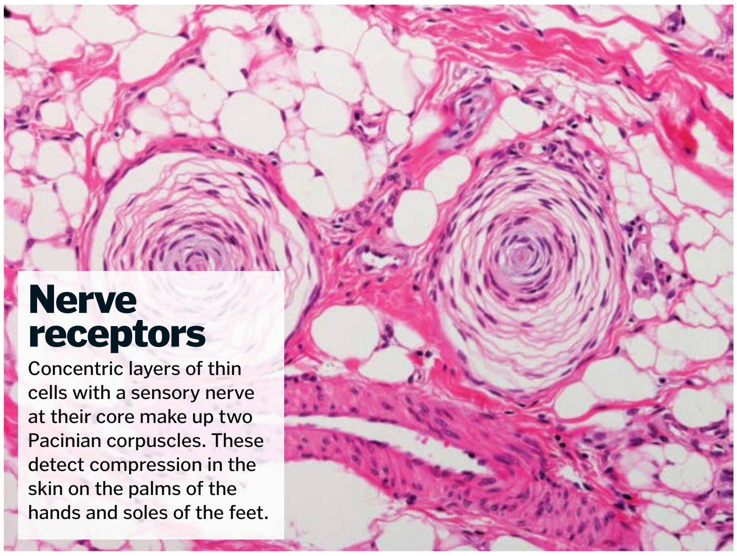
Learn more

The International Images for Science (IISE) awards are organised by the Royal Photographic Society and sponsored by Siemens. To find out which images won the 2015 awards and learn how you can enter the 2016 competition, visit **www.rps.org**.



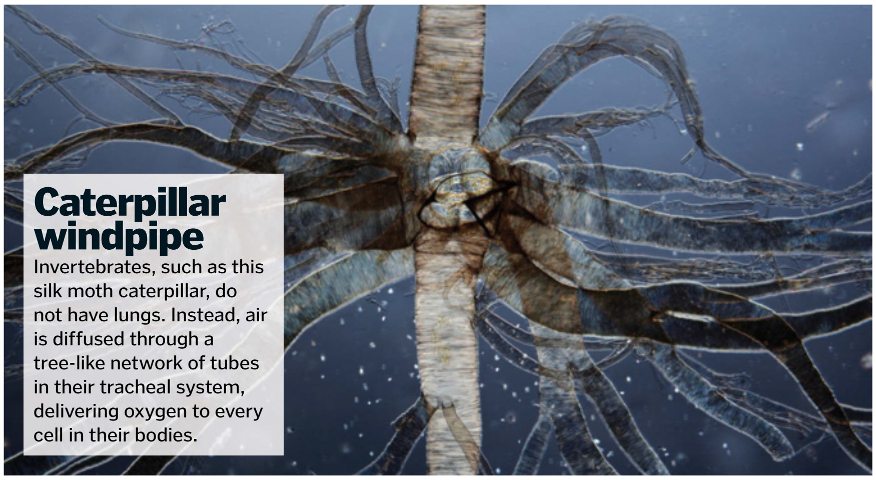
Sticking plaster

Silver is incorporated into the fibres of adhesive dressings because its antibacterial properties can help wounds to heal.



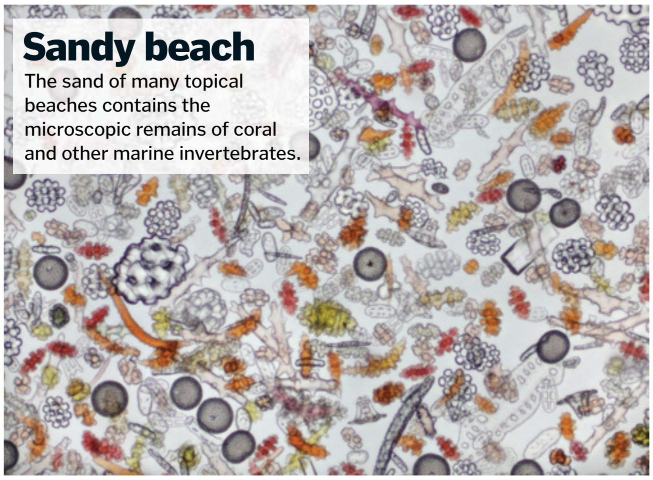
Nerve receptors

Concentric layers of thin cells with a sensory nerve at their core make up two Pacinian corpuscles. These detect compression in the skin on the palms of the hands and soles of the feet.



Caterpillar windpipe

Invertebrates, such as this silk moth caterpillar, do not have lungs. Instead, air is diffused through a tree-like network of tubes in their tracheal system, delivering oxygen to every cell in their bodies.

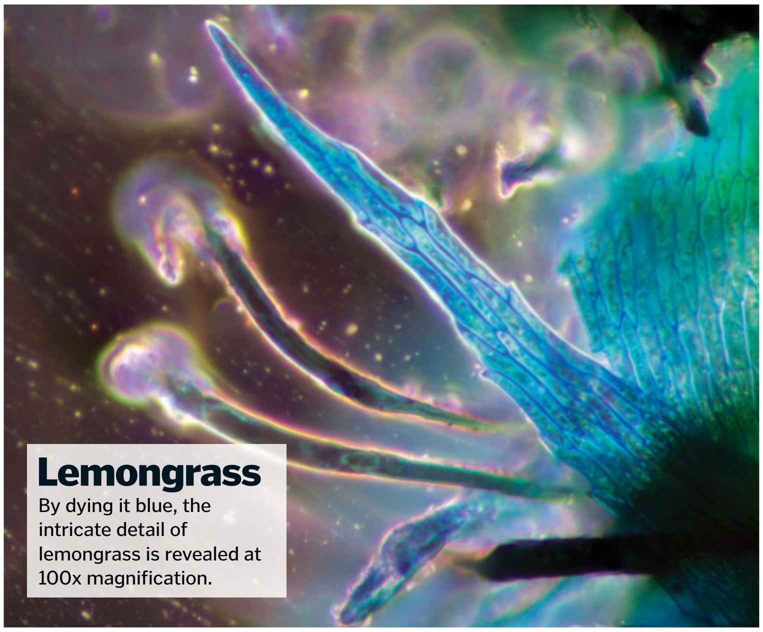


Sandy beach

The sand of many topical beaches contains the microscopic remains of coral and other marine invertebrates.

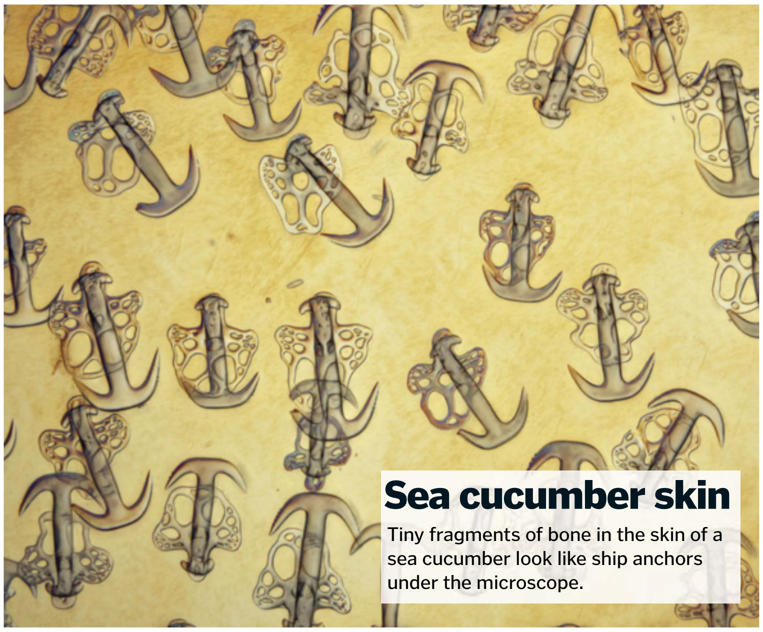
Limpet teeth

The teeth (pictured in black) of limpets are made of the strongest natural material known to man.



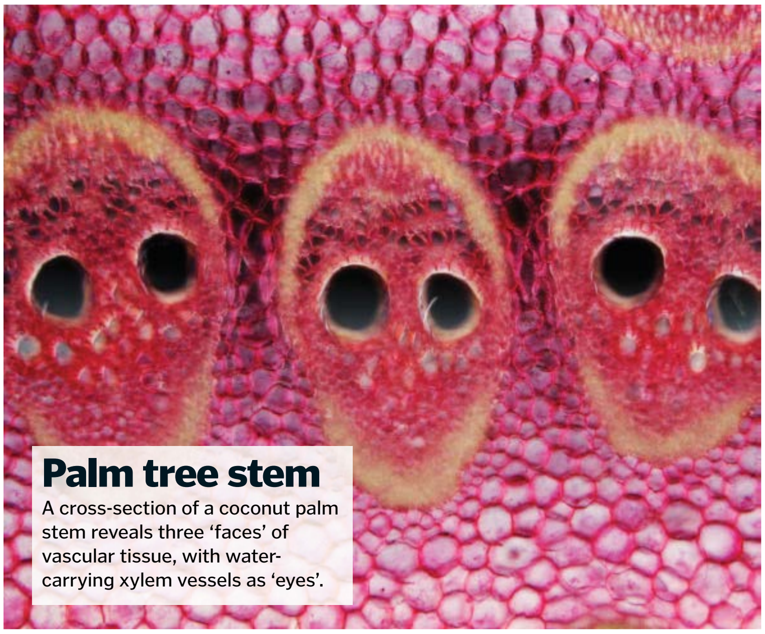
Lemongrass

By dying it blue, the intricate detail of lemongrass is revealed at 100x magnification.



Sea cucumber skin

Tiny fragments of bone in the skin of a sea cucumber look like ship anchors under the microscope.



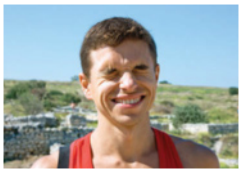
Palm tree stem

A cross-section of a coconut palm stem reveals three 'faces' of vascular tissue, with water-carrying xylem vessels as 'eyes'.

© Royal Photographic Society/ Dr Jeffrey Kerr/ Kelvin John Archer/ Dr David Maitland/ Stephen Gschmeissner

The fastest clichés

Which of these old phrases would circle Earth the quickest?

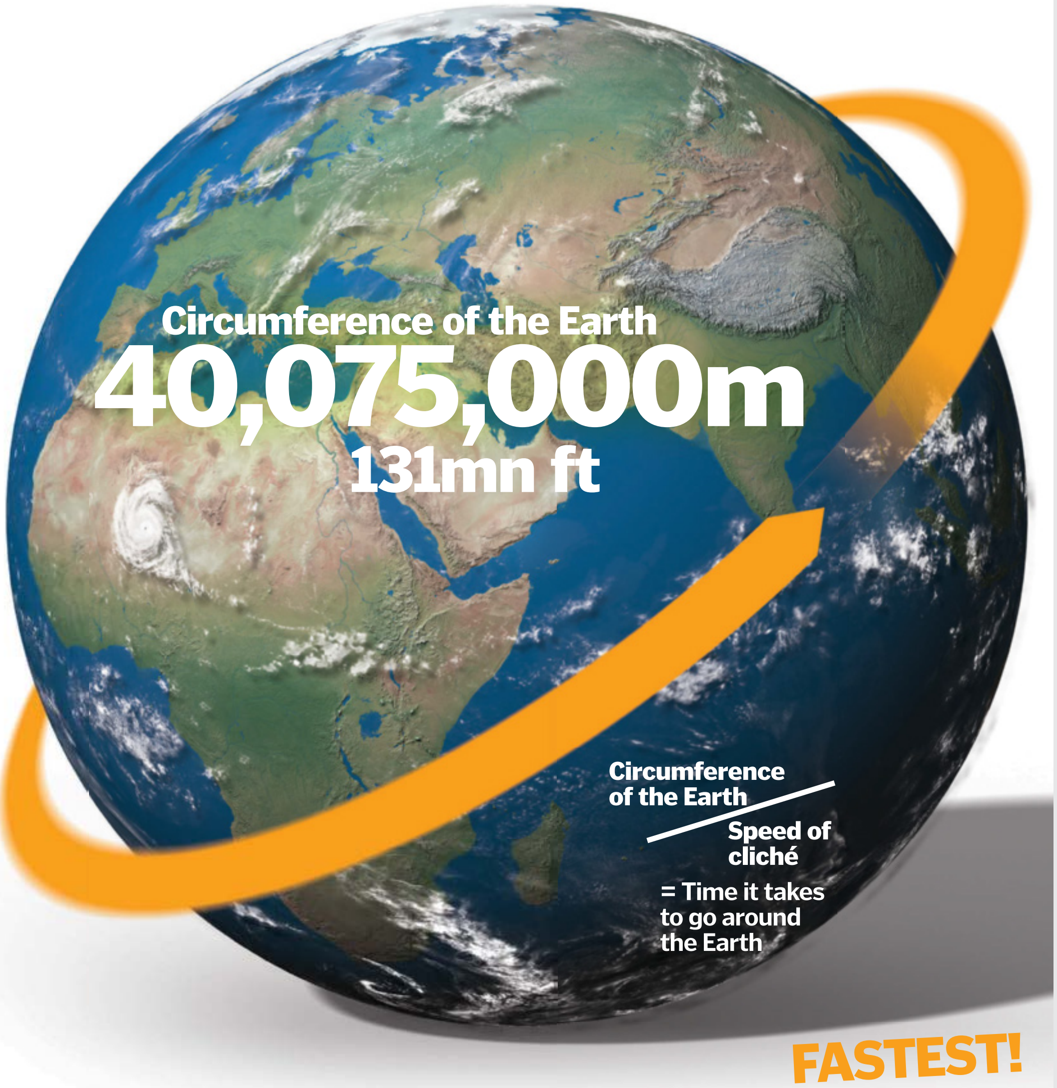


BLINK OF AN EYE
0.03m/s
0.1ft/s
42 years

DROP OF A HAT
5.7m/s
20.5ft/s
81 days

LIKE WILDFIRE
6.3m/s
20.5ft/s
73.6 days

ONE FELL SWOOP
107m/s
352ft/s
4.3 days



Circumference of the Earth
40,075,000m
131mn ft

$$\frac{\text{Circumference of the Earth}}{\text{Speed of cliché}}$$ = Time it takes to go around the Earth

SUPERSONIC SPEED
344m/s
328,084ft/s
32.4 hours

SPEEDING BULLET
1,200m/s
3,937ft/s
9.3 hours

FAST AS LIGHTNING
100,000m/s
328,084ft/s
6.7 mins

FASTEST!

SPEED OF LIGHT
299,792,458m/s
328,084ft/s
0.134 secs

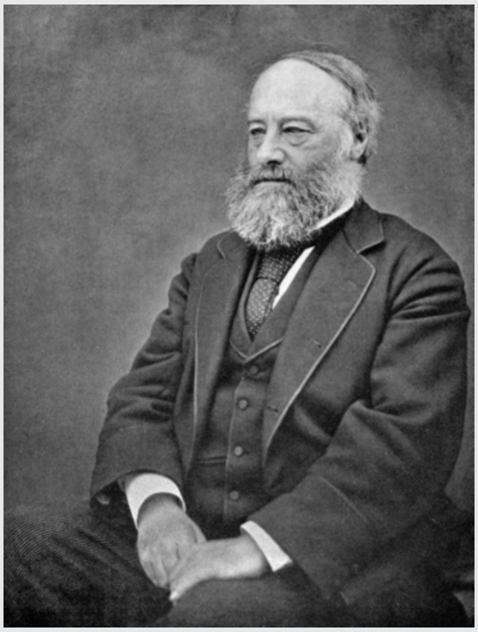
Conservation of energy

This law states that you can neither create nor destroy energy

Forming the foundation of our scientific understanding of energy, this law is seen in action in almost every process we carry out each day. Our bodies are essentially machines that turn one kind of energy into another, but the underlying principle in this process is that energy is never be lost nor created; it is only converted.

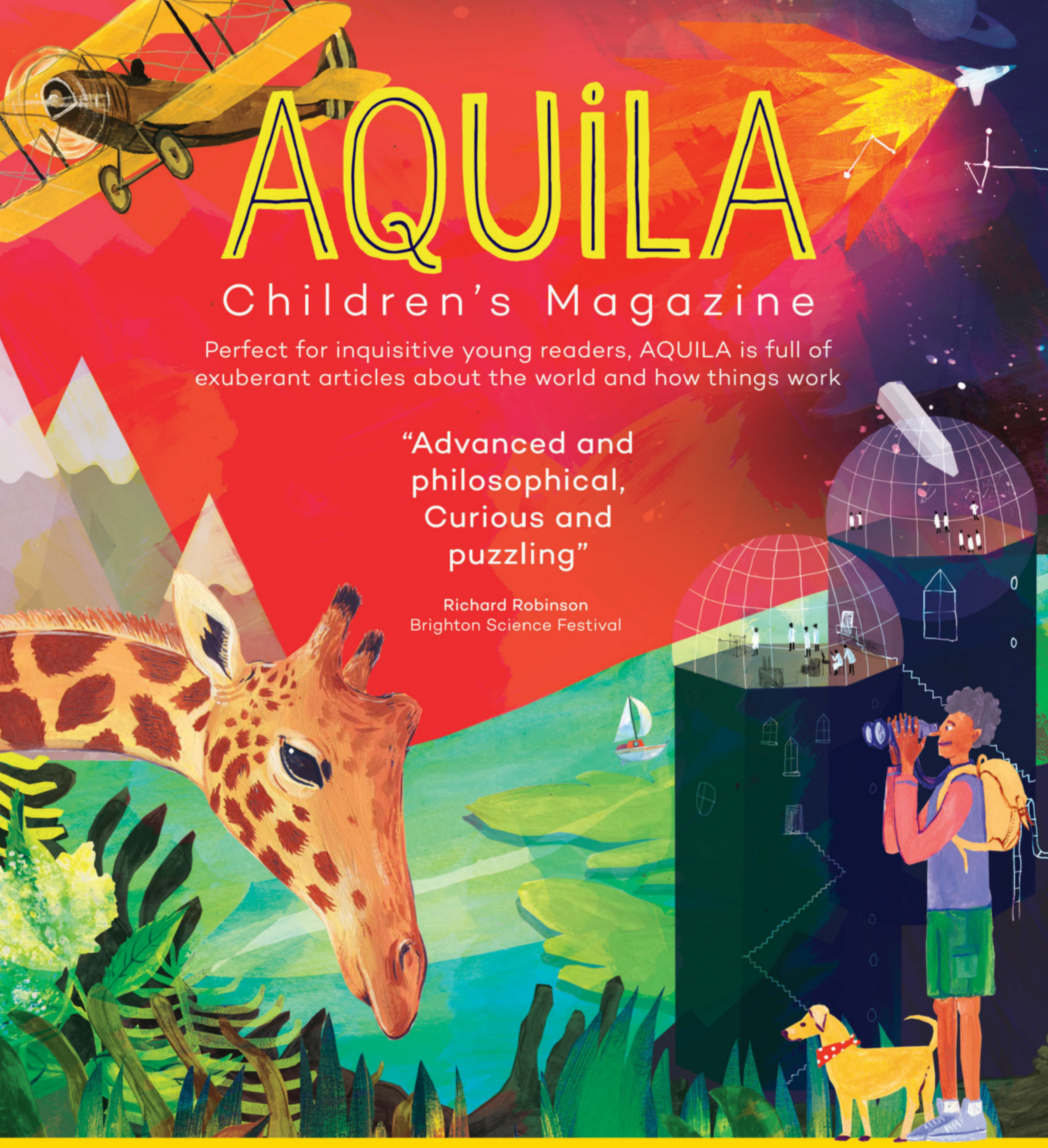
Although it seems obvious that twice the fuel provides twice the energy, it actually took an ingenious piece of scientific apparatus to prove this, devised by English physicist James Joule. He used the energy created by a falling weight to drive a paddle wheel sealed inside a container of water. He reasoned that the plummeting weight would transfer all of its energy into the paddle wheel, which would in turn stir the water and raise its temperature.

Joule knew how much energy it took to warm a specific mass of water, therefore he was able to calculate how much energy the water had gained. He was thrilled to discover that the figure he calculated matched the energy lost by the falling weight, which proved the theory to the scientific community and the world. Due to the huge significance of his discovery, the unit for energy was named after him; the 'Joule' is still in use today.



James Prescott Joule was one of the first people to confirm the law of conservation of energy

© Dreamstime; NASA



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FUTURE OF

In the year 2050, dining at your favourite restaurant is likely to be an altogether different experience. After being greeted by your robot waiter and taken to your table on a hoverboard, you will be left to peruse the holographic menu at your leisure. As you scroll through the options, you'll notice that all of the usual dishes are still there, but with a few unusual twists thrown in.

For your starter, you'll tuck into a delicious Caesar salad containing protein-rich mealworms instead of chicken, and sprinkled with crunchy croutons made using cricket flour. Next, your android waiter 2.0 will bring over the mouth-watering main course; a meaty burger that has been grown in a Petri dish, garnished with crisp lettuce freshly picked from an underground farm and juicy tomato that has been genetically modified to contain extra vitamins. Then, if you still have room for dessert, you'll be able to choose from a range of sweet treats that have been designed on a computer and printed directly onto the plate.

These unconventional dishes may seem bizarre and perhaps stomach-churning to us now, but in the future they could help to solve a global food crisis. Over the next 35 years, the world's population is expected to exceed nine billion, meaning an extra two billion hungry mouths to feed. To fulfil this demand, the amount of food we grow will need to increase by 70 per cent, but with most of the planet's farmland already being used, and billions of its inhabitants already undernourished, this is going to be a major challenge.

Today's global food industry is already unsustainable, with agriculture responsible for

Creepy-crawly protein
Munching on mealworms and crickets is a healthier and more environmentally friendly alternative to eating beef or chicken.

3D-printed meals
Preparing your dinner is about to get a whole lot easier thanks to the 3D printed food revolution.

Lab-grown meat
No animals need to be harmed in the making of your favourite meals, as scientists can grow meat from cells.

Genetically modified veg
Fruit and veggies can be tweaked to make them easier to grow, and more nutritious and tastier too.

FOOD

Why you'll be eating lab-grown burgers, 3D-printed pizzas & insects

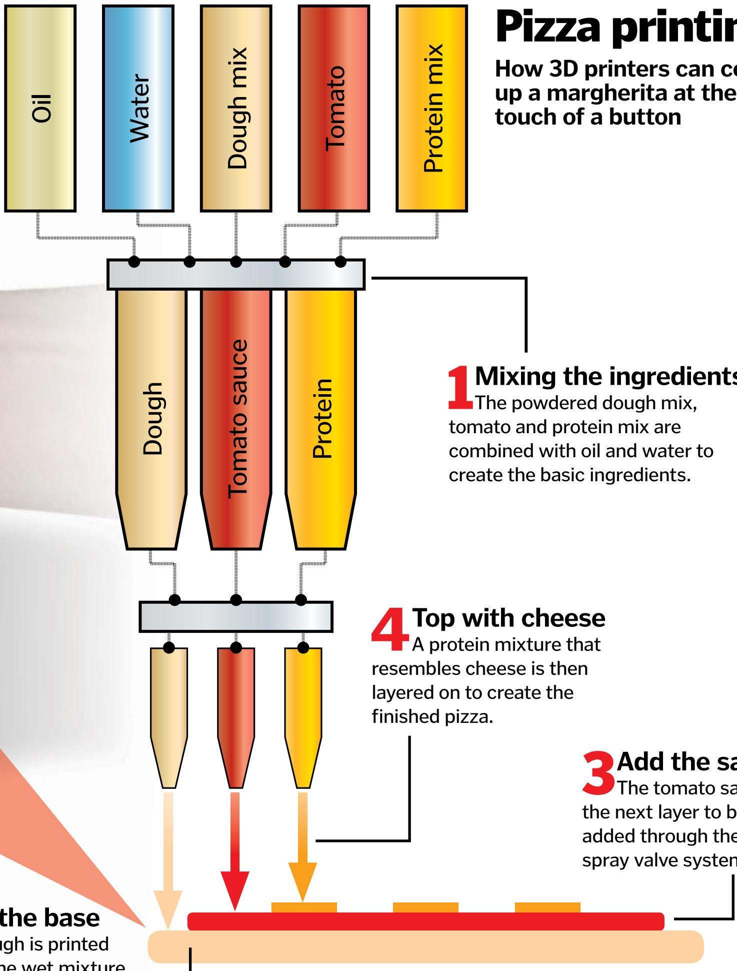
almost a third of all human-caused greenhouse gas emissions. From the nitrous oxide given off by crop fertilisers, to the carbon dioxide generated as the produce is transported around the world, these gases are trapping heat in the atmosphere and gradually warming the surface. In turn, the changing climate makes it difficult to grow more crops, and so scientists will need to step in more and more to help. By genetically modifying the plants we grow, not only can the more vulnerable species be made able to withstand harsher, inhospitable environments, but the hardier species that can survive could also be made more nutritious to ensure we all get the vitamins and minerals we need.

Although growing fruit and vegetables generates a great deal of greenhouse gas, it is livestock production that is the biggest contributor to global emissions. It is estimated that producing one 230-gram (half-pound) hamburger generates the same amount of greenhouse gas as driving a typical passenger car for 16 kilometres (ten miles). Among these gasses is methane, which is about 25 times more effective at warming the planet than carbon dioxide. As demand for meat grows, so does the list of negative consequences for our planet, so something needs to be done very soon.

Of course, one simple solution to the problem is to eat less meat, but for a mostly carnivorous global population that gets through around 285 million tons of the stuff each year, this idea is unlikely to catch on. Therefore, tasty alternatives need to be found, and our idea of what we consider to be meat may need to change too. For example, the beef and chicken in your burgers and burritos could soon be swapped for crickets and locusts, or perhaps be grown in a lab instead of on a farm.

In fact, even traditional farms as we know them are likely to look completely different in just a few decades time. Gone will be the days of farmers having to drive tractors and milk the cows themselves, as autonomous machines are already starting to take over and make the industry more efficient.

Once these eco-friendly and sustainable foods have been harvested, we might not recognise the products that hit the shelves. Instead of packets and tins, your local supermarket will sell ingredients in cartridges that you can load into your 3D printer at home. Then, with a press of a button, you can sit back and relax while the machine builds a delicious dish – layer by layer – that is sure to impress your dinner party guests.



Pizza printing

How 3D printers can cook up a margherita at the touch of a button

1 Mixing the ingredients The powdered dough mix, tomato and protein mix are combined with oil and water to create the basic ingredients.

2 Print the base The dough is printed first, with the wet mixture layered directly onto a hot plate and cooked.

3 Add the sauce The tomato sauce is the next layer to be added through the spray valve system.

4 Top with cheese A protein mixture that resembles cheese is then layered on to create the finished pizza.

3D-printed meals

3D printing is already being used to create car parts, clothes and even prosthetics, but next on the agenda is your dinner. You will soon be able to make a meal from scratch simply by choosing a recipe and clicking print. 3D food printers that can produce intricate edible designs from sugar and chocolate already exist, but the Foodini, a 3D printer that can create a wide range of both savoury and sweet foods, is due to go on sale in 2016. Once you select your desired recipe, Foodini will tell you which ingredients to place into its food capsules, then it will start printing your dish in layers until it is ready for you to cook in the oven or pan. It can create crackers, pizzas, veggie burgers and even ravioli, allowing you to keep track of exactly what goes into your meal. As well as benefiting you at home, 3D printing food could also help to improve the quality and variety of meals available for astronauts on long duration space missions. A NASA-funded project has developed a machine that can print a pizza from dried ingredients with a 30-year shelf life, meaning it could someday feature on a menu on Mars.

Beijing Hesion 3D Technology is developing a pancake-printing machine, to satisfy those creative sweet treat cravings

© Corbis; Dreamstime

Lab-grown meat

Discover how scientists can create burgers without harming cows

Global demand for meat is expected to increase by more than two-thirds in the next 40 years, and we are already struggling to cope. Current methods for producing meat are not very sustainable, as huge amounts of land and other resources are needed to rear livestock. As these assets get harder to come by, the price of meat will continue to rise, meaning that it could soon become an unaffordable luxury. The meat industry is also having a negative environmental impact on the planet, with the animals releasing huge amounts of methane, a greenhouse gas that contributes to global warming.

Many scientists believe the solution to this looming problem is cultured meat grown in the lab, and a team from Maastricht University in the Netherlands has already perfected the technique. By extracting stem cells from a living cow they have been able to grow muscle tissue and turn it into a burger that tastes a lot like the real thing. The cells taken from just one cow could produce 175 million burgers, which would normally require meat from 440,000 cows; better still, the animal remains unharmed. It's not just beef that can be grown this way either, as the method can easily be replicated to create chicken, pork and other meats too.

Before you start planning your lab-grown barbecue though, scientists believe it could be another ten to 20 years before the meat becomes commercially available. It currently costs around €250,000 (£185,000 or $280,000) to produce a single burger, but as the method is refined, cultured meat could become cheaper than the conventional kind grown on farms by 2035.

> "Cells taken from just one cow could produce 175 million burgers"

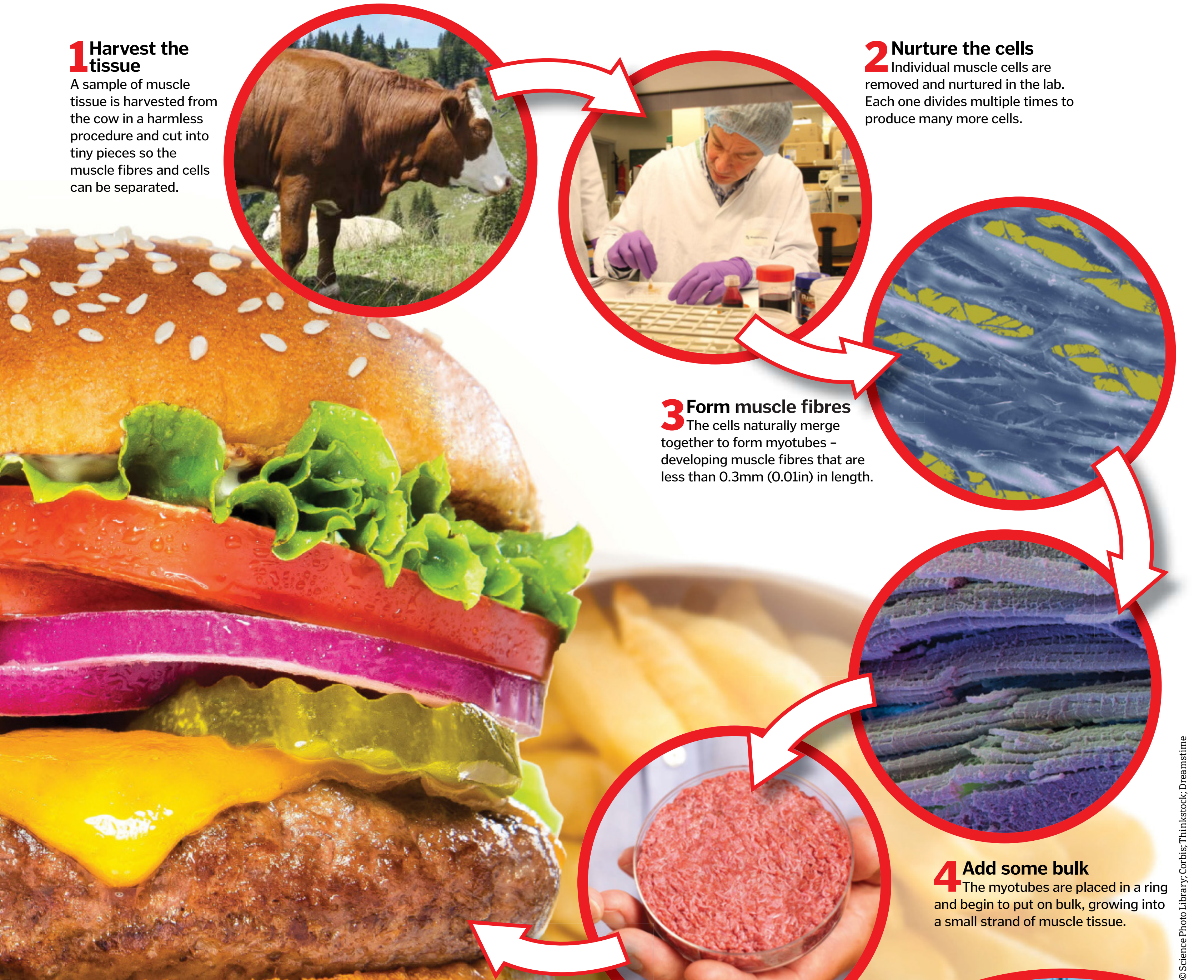
How to build a burger

The cheese and meat in an Impossible Burger are made entirely from plants

Turning plants into beef

If a lab-grown burger doesn't get your mouth watering, then maybe one made entirely from plants will. Impossible Foods has discovered a way to make meat and cheese without animals, yet still promise that it will 'delight and nourish the most discerning meat lover'.

From plants such as greens, grains and beans, they extract proteins that have a meaty texture, flavour or aroma. The proteins are then mixed with amino acids, vitamins and fats – also from plants – to create the three main components of meat; muscle, connective tissue and fat. When these are combined in the right proportions, they form a burger that looks, tastes and smells just like ground beef. The Impossible Burgers are expected to go on sale in 2016, and will be followed by a range of other meats and dairy products, all made entirely from plants.



1 Harvest the tissue

A sample of muscle tissue is harvested from the cow in a harmless procedure and cut into tiny pieces so the muscle fibres and cells can be separated.

2 Nurture the cells

Individual muscle cells are removed and nurtured in the lab. Each one divides multiple times to produce many more cells.

3 Form muscle fibres

The cells naturally merge together to form myotubes – developing muscle fibres that are less than 0.3mm (0.01in) in length.

4 Add some bulk

The myotubes are placed in a ring and begin to put on bulk, growing into a small strand of muscle tissue.

5 Layer the tissue

It takes approximately 20,000 of these strands layered together to form a normal sized burger.

© Science Photo Library; Corbis; Thinkstock; Dreamstime

The insect diet

People throughout Africa and Asia regularly eat bugs as a source of protein, but these creepy crawly snacks could soon catch on in the Western world, too. The United Nations' Food and Agriculture Organization has suggested that insects are a healthier, more environmentally friendly and more sustainable alternative to conventional meat, and insect farms are already popping up across the world.

Although they might not seem appetising, many insects are very nutritious, containing lots of good fats, calcium, iron and zinc. Rearing them also requires much less land than traditional meat production and results in considerably fewer greenhouse gas emissions.

As they are cold-blooded, insects are much more efficient at converting food into protein, with cows needing 12 times as much food as crickets to produce the same amount of protein. They can also be fed on food scraps and animal manure to help recycle waste.

The Micronutris insect farm in France breeds many species of insect for human consumption

Farms of tomorrow

How technology will help farmers cope with increasing demand

With more and more mouths to feed, farms need to be run as efficiently as possible in order to keep up with demand. As a result, many farmers are turning to new technologies for help, using precision systems to make many of their day-to-day tasks easier.

For example, GPS is already widely used to ensure tractors are driven in straight lines across fields, preventing them from overlapping their routes. This helps to save fuel, fertiliser and seed that would otherwise be wasted as the farmer covers the same piece of land again and again. However, in the not-so-distant future, farmers may not need to drive their tractors at all, with several self-driving machines currently in development. Other farming machinery is also becoming increasingly hi-tech, with robots being used to feed and milk livestock more efficiently.

Although some of this cutting-edge tech is unaffordable for many farmers at the moment, the farms of the future are likely to be incredibly large-scale businesses, which need to be almost entirely automated in order to be cost-effective. So instead of mucking out the pigs and feeding the cows, future farmers will be able to sit back and let the machines do all the hard work, while they control everything from their smartphone or tablet.

Driverless tractors
Although not yet commercially available, many self-driving tractors are in development. The Autonomous Tractor Company's Spirit tractor will navigate by sensing signals from a series of transponders set up around the field and will use radar to detect any obstacles in its way.

Smartphones and tablets
There's a whole host of apps that can help farmers run their farms more effectively. From checking the weather to registering livestock, a lot of tasks can be made easier using digital devices such as smartphones and tablets.

Electronic tags
Attaching electronic tags to livestock can help farmers keep track of their animals' health and habits as they send and receive signals from machines and alert the farmer if individual animals are not being fed or milked enough.

Going underground

An abandoned World War II bomb shelter may seem like an unusual location for growing vegetables and herbs, but subterranean farms could be the future of crop growing. With conventional farmland becoming more and more scarce, and crops at risk from changing weather, indoor alternatives can be used to fulfil the demand and provide a more controllable growing environment. To grow plants indoors, hydroponic systems can be used. Instead of soil, the plants sit in trays of water enriched with nutrients, while banks of LEDs overhead provide light for energy.

The Growing Underground farm 30 metres (100 feet) beneath the streets of London uses a controlled hydroponics system to grow crops all year round, and can deliver its produce to the city's restaurants and wholesalers within just four hours of being harvested. As only green energy is used to power the lights, the farm is also carbon-neutral.

Growing Underground has turned an abandoned bomb shelter into a sustainable farm

DID YOU KNOW? *Most of the sugar beet, corn and soybean crops growing in the US have been genetically engineered*

> *"GPS is already widely used to ensure tractors are driven in straight lines"*

Automated milking machines

Robot milking machines allow cows to be milked whenever they want, so the farmer doesn't have to herd them up at 5am. The machine knows which cow is which and automatically attaches the milking teats when they enter the booth.

Robot livestock feeders

Automated feed pushers can sweep the livestock's feed towards them when they are lined up at the feed fence, ensuring that they have a constant supply of food and giving the farmer one less back-breaking task to do.

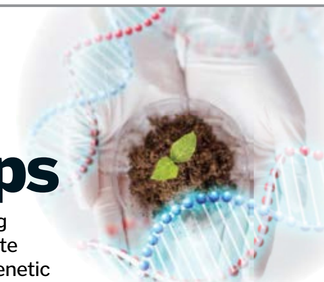
Aerial drones

Drones can be used to produce accurate maps of farmland to calculate fertiliser needs, give farmers a bird's eye view of their land to help them monitor crops and even scare away pests before they can damage the yield.

Farm management software

Tech-savvy farmers can manage many aspects of their farm from their computer, using software to map their land, calculate the resources they need and monitor their livestock. This can help decrease wastage and boost productivity, making the business more profitable.

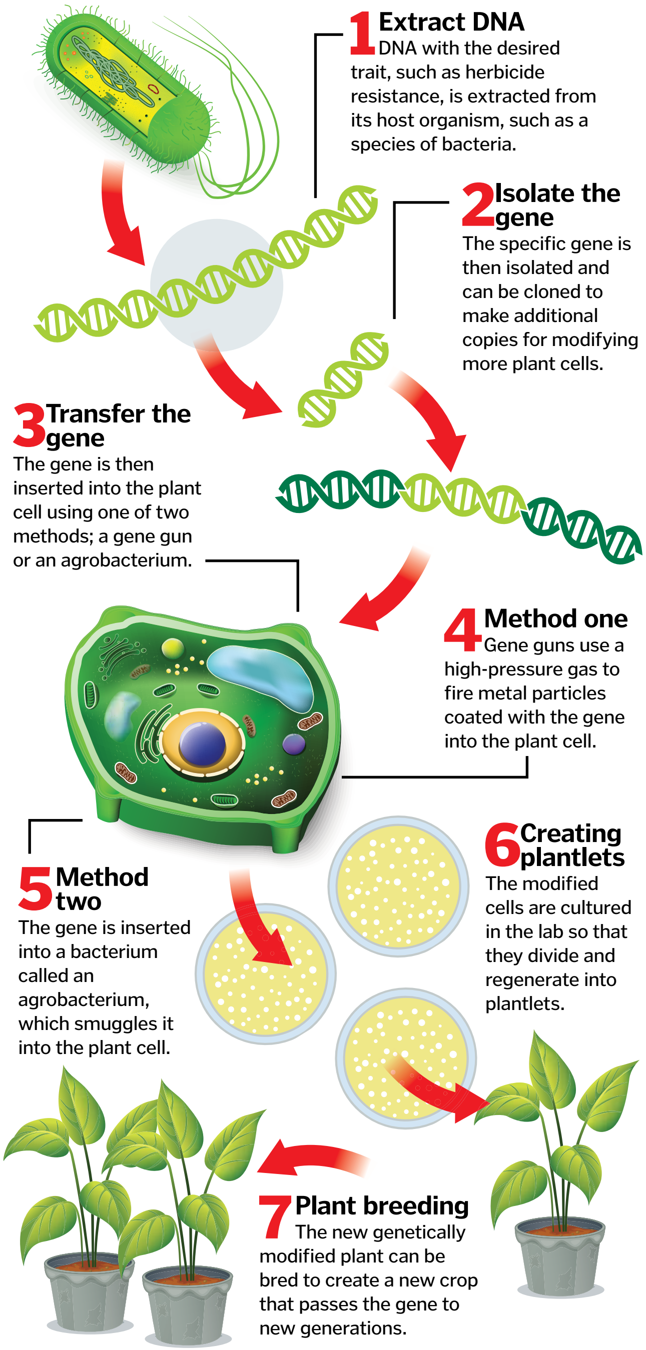
Genetically modified crops



Growing enough food for the rapidly growing population of a planet with a changing climate would be more or less impossible without genetic engineering. By modifying the genes of plants, new crops can be created that are resistant to weed-killing herbicides and disease-causing pests, or are able to grow in inhospitable conditions. These genetically modified organisms (GMOs) can also be created to produce fruit and vegetables that stay ripe for longer, reducing wastage, or even contain more of the vitamins we need to stay healthy. Although there is some controversy surrounding GMOs, there is currently no evidence that they are bad for your health; people and livestock have been consuming them for decades with no ill effects.

How to genetically modify a plant

The simple steps for creating a modified food crop



1 Extract DNA
DNA with the desired trait, such as herbicide resistance, is extracted from its host organism, such as a species of bacteria.

2 Isolate the gene
The specific gene is then isolated and can be cloned to make additional copies for modifying more plant cells.

3 Transfer the gene
The gene is then inserted into the plant cell using one of two methods; a gene gun or an agrobacterium.

4 Method one
Gene guns use a high-pressure gas to fire metal particles coated with the gene into the plant cell.

5 Method two
The gene is inserted into a bacterium called an agrobacterium, which smuggles it into the plant cell.

6 Creating plantlets
The modified cells are cultured in the lab so that they divide and regenerate into plantlets.

7 Plant breeding
The new genetically modified plant can be bred to create a new crop that passes the gene to new generations.

© Alamy; Corbis; Rex Features; Thinkstock; Dreamstime

How hearing aids work

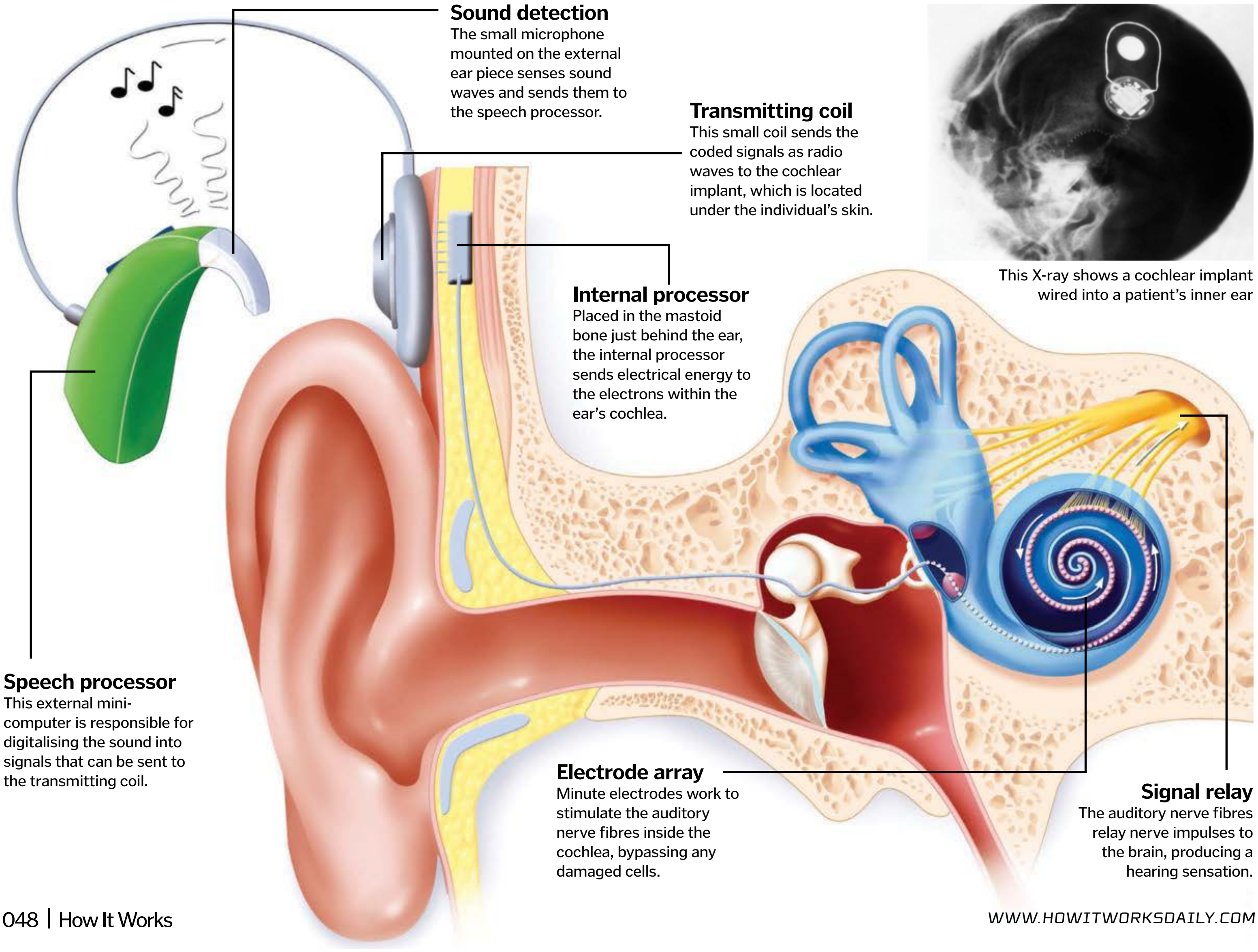
A closer look at the tiny gadgets that can amplify sound

Hearing aids are carefully fitted to get the best results

It is believed that the ability to hear evolved in animals as an early warning system, but for humans it provides us with so much more than that. Unfortunately, some people are born with little or no hearing ability, and many more struggle with faded hearing as they get older. Thanks to the brilliance of modern science, many people that suffer from such problems can now use a hearing aid to revitalise this crucial ability.

Traditional hearing aids essentially work by boosting the volume of the sound that reaches a person's ear, much like guitar amplifiers boost the instrument's sound. Although this works well, it is relatively low-tech compared to some of the hearing solutions available today. One such device is the cochlear implant, which enables sound to be transferred directly through your auditory (hearing) nerves to the brain. This tends to be a much more effective solution than a hearing aid, allowing patients to reconnect with sounds they previously struggled to hear and better understand other people's speech.

Only one fifth of people who could benefit from a hearing aid seek help, which illustrates just how commonplace this technology could become. The stigma of needing to wear one is far outweighed by the possible benefits, especially as they are now mostly hidden from view. In the future it might be possible to completely regenerate the cochlea, making hearing aids redundant and returning the joy of sound to many.



Sound detection
The small microphone mounted on the external ear piece senses sound waves and sends them to the speech processor.

Transmitting coil
This small coil sends the coded signals as radio waves to the cochlear implant, which is located under the individual's skin.

Internal processor
Placed in the mastoid bone just behind the ear, the internal processor sends electrical energy to the electrons within the ear's cochlea.

Speech processor
This external mini-computer is responsible for digitalising the sound into signals that can be sent to the transmitting coil.

Electrode array
Minute electrodes work to stimulate the auditory nerve fibres inside the cochlea, bypassing any damaged cells.

Signal relay
The auditory nerve fibres relay nerve impulses to the brain, producing a hearing sensation.

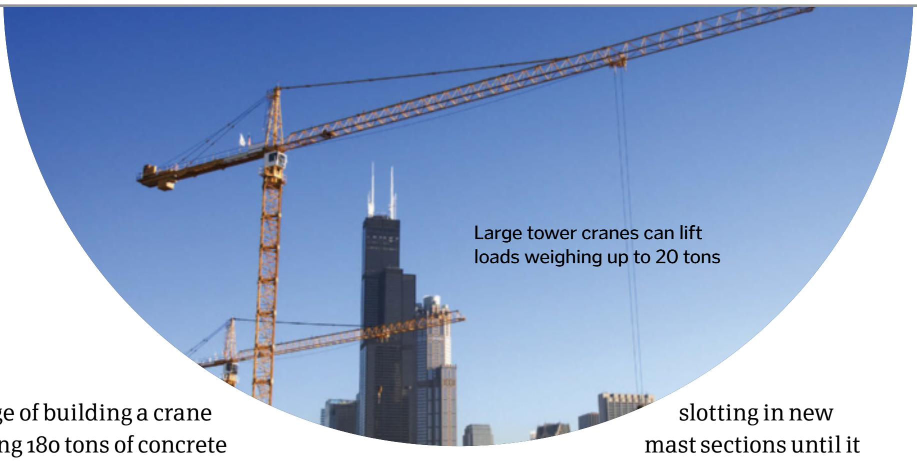
This X-ray shows a cochlear implant wired into a patient's inner ear

© Alamy; Corbis; Thinkstock

DID YOU KNOW? *The largest tower crane in the world is the Kroll K10000, and was designed to build nuclear power plants*

How are cranes built?

The incredible engineering that enables cranes to build themselves


Large tower cranes can lift loads weighing up to 20 tons

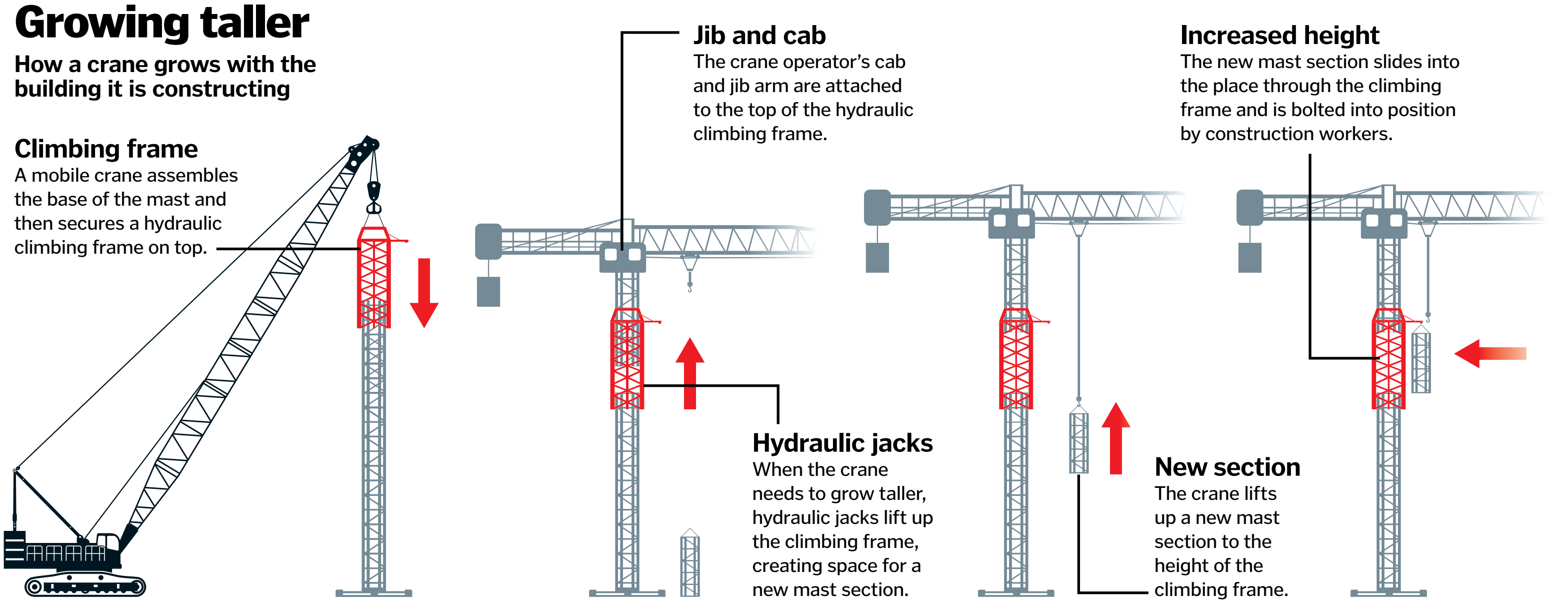
Tower cranes are a common sight on city skylines, and an essential part of any building site, but have you ever wondered how they came to be there? The only thing capable of building a structure to such impressive heights is a crane, so these incredible engineering marvels must build themselves at the construction site, with just a little help from man and machine.

The first stage of building a crane involves pouring 180 tons of concrete into the ground to form the base that the steel mast is embedded into. This helps ensure the structure is stable, and won't topple over in the wind. Once the concrete has set, a small mobile crane builds the first section of the vertical mast and attaches a horizontal arm, called a jib, on top. From here, the crane builds itself, slotting in new mast sections until it reaches the desired height.

Unsupported, a typical crane can reach around 80 metres (265 feet) in height, but even greater heights are achievable if they are tethered to a building for support. When their job is done, they can be dismantled by reversing the process. ⚙

Growing taller

How a crane grows with the building it is constructing



Climbing frame
A mobile crane assembles the base of the mast and then secures a hydraulic climbing frame on top.

Jib and cab
The crane operator's cab and jib arm are attached to the top of the hydraulic climbing frame.

Hydraulic jacks
When the crane needs to grow taller, hydraulic jacks lift up the climbing frame, creating space for a new mast section.

New section
The crane lifts up a new mast section to the height of the climbing frame.

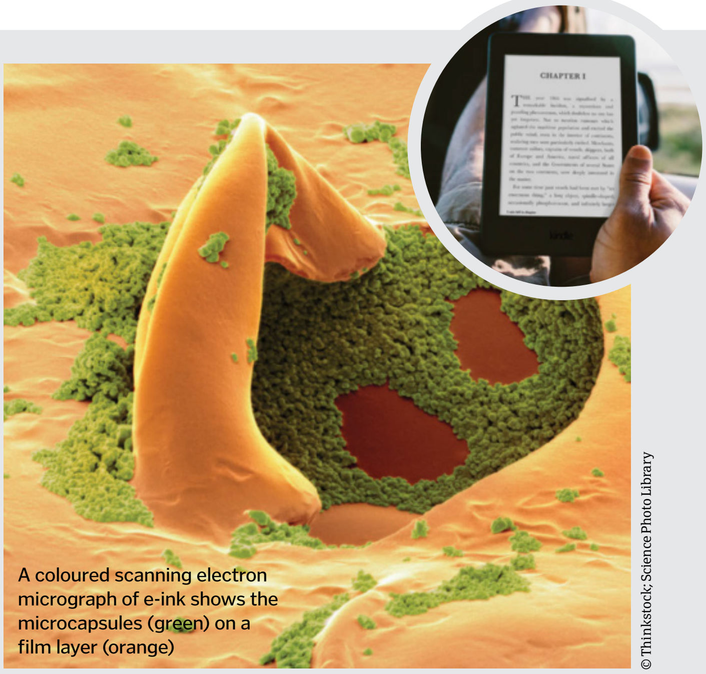
Increased height
The new mast section slides into the place through the climbing frame and is bolted into position by construction workers.

What is e-ink?

Take a look inside the clever display of your e-reader

E-readers use electronic paper displays containing electronic ink. This e-ink is made up of millions of tiny microcapsules, each about the diameter of a human hair, sandwiched between two layers of transparent film and electrodes. Each microcapsule contains positively charged white particles and negatively charged black particles suspended in a clear fluid. When the electrode beneath the microcapsules applies a negative electric charge, the negatively charged black particles are repelled to the top of the capsule, making the film above appear black. Then, when a positive charge is applied, the white particles are repelled instead, making the film appear white. By applying the correct charge at different points across the display, black text and graphics can be formed, with the microcapsules acting like pixels on a computer screen.

A major benefit of an e-ink display over a traditional LCD screen is that it doesn't need a backlight, so power is only required when the display is changed. This helps to extend the device's battery life, and also prevents eyestrain typically caused by staring at backlit screens for long periods of time. ⚙


A coloured scanning electron micrograph of e-ink shows the microcapsules (green) on a film layer (orange)

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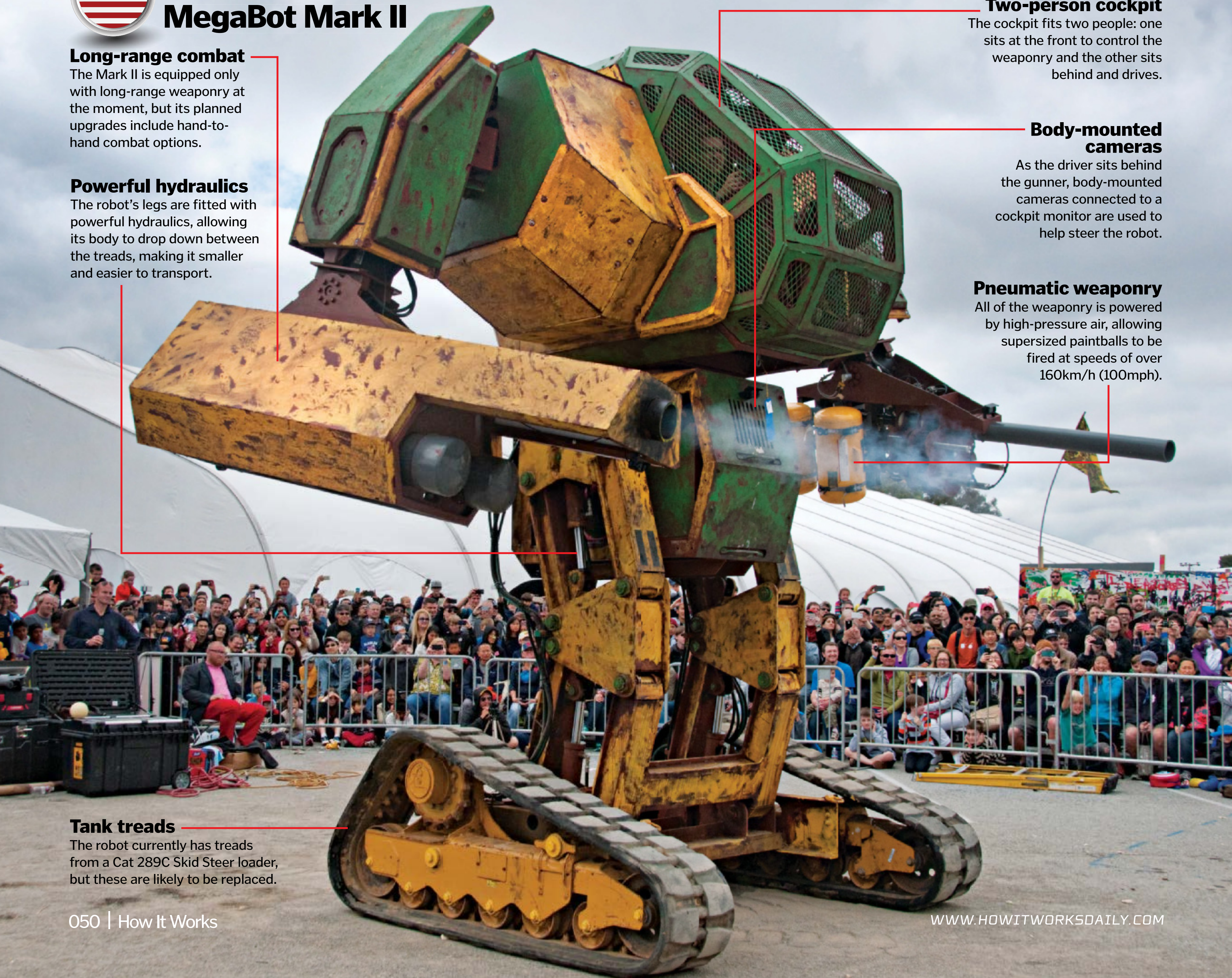
ROBOT WARS

Discover the next big thing in sports: giant mechanical monsters that fight to the death

America's MegaBot Mark II



Long-range combat
The Mark II is equipped only with long-range weaponry at the moment, but its planned upgrades include hand-to-hand combat options.

Powerful hydraulics
The robot's legs are fitted with powerful hydraulics, allowing its body to drop down between the treads, making it smaller and easier to transport.

Tank treads
The robot currently has treads from a Cat 289C Skid Steer loader, but these are likely to be replaced.

Two-person cockpit
The cockpit fits two people: one sits at the front to control the weaponry and the other sits behind and drives.

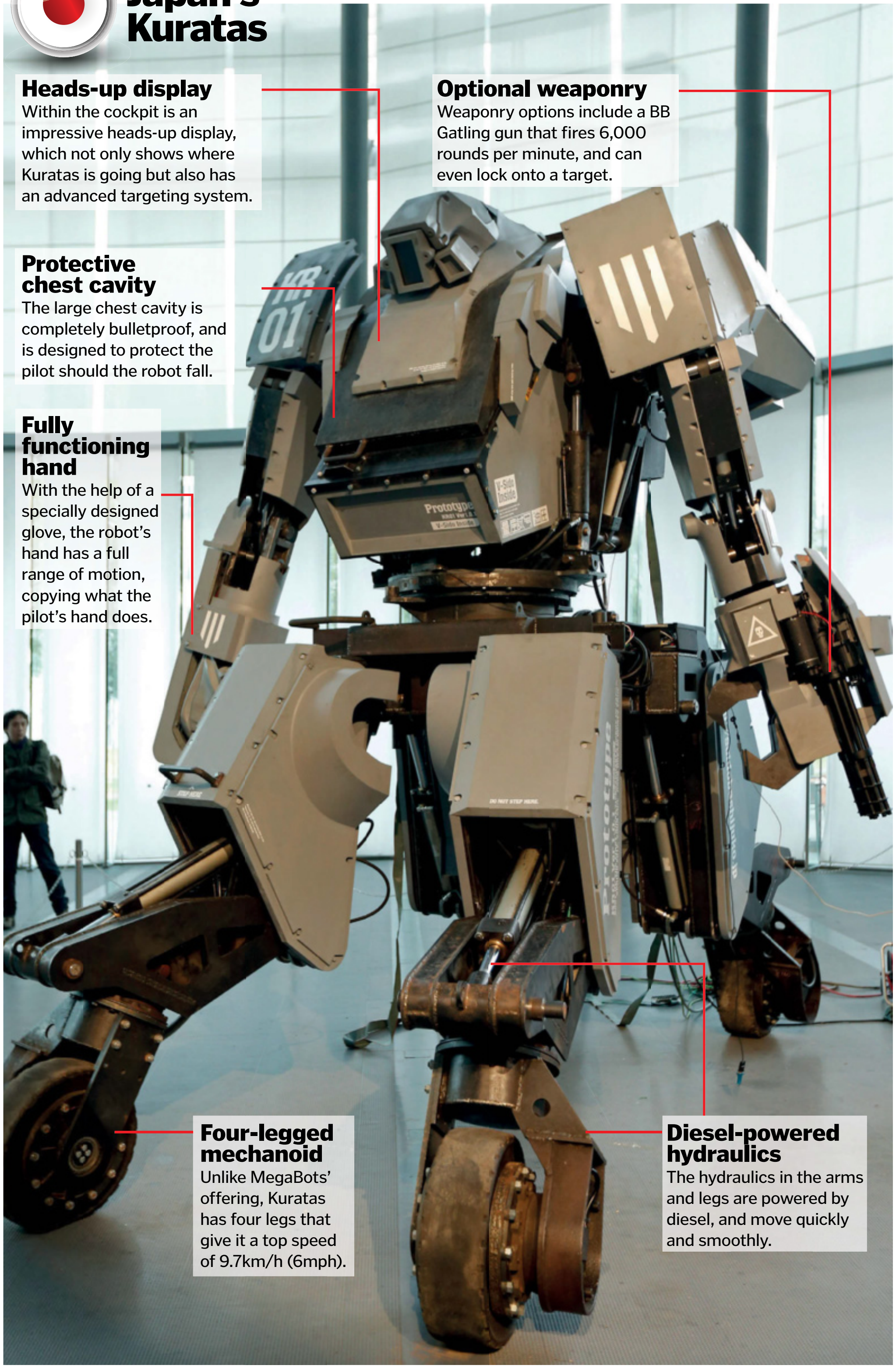
Body-mounted cameras
As the driver sits behind the gunner, body-mounted cameras connected to a cockpit monitor are used to help steer the robot.

Pneumatic weaponry
All of the weaponry is powered by high-pressure air, allowing supersized paintballs to be fired at speeds of over 160km/h (100mph).

Since the birth of science fiction, cinema has been pitting giant robots against each other in colossal fights to the death. The closest we ever got in real life was UK television show *Robot Wars* (and its US counterpart *Battlebots*), where radio-controlled machines went to battle in an area rigged with flame pits, angle grinders and other robot death-traps. Now, we're set to see towering automatons go head-to-head, but these creations won't be judged on damage, control, style and aggression. The winner will be the one left standing.

American startup MegaBots Inc has created their very own piloted, humanoid robot, the MegaBot Mark II. Standing at an impressive 4.6 metres (15 feet) and weighing 5.4 tons, it employs cutting-edge robotics to deliver metal-splitting blows and fire weaponry as the pilots command.

Japan's Kuratas



Heads-up display
Within the cockpit is an impressive heads-up display, which not only shows where Kuratas is going but also has an advanced targeting system.

Optional weaponry
Weaponry options include a BB Gatling gun that fires 6,000 rounds per minute, and can even lock onto a target.

Protective chest cavity
The large chest cavity is completely bulletproof, and is designed to protect the pilot should the robot fall.

Fully functioning hand
With the help of a specially designed glove, the robot's hand has a full range of motion, copying what the pilot's hand does.

Four-legged mechanoid
Unlike MegaBots' offering, Kuratas has four legs that give it a top speed of 9.7km/h (6mph).

Diesel-powered hydraulics
The hydraulics in the arms and legs are powered by diesel, and move quickly and smoothly.

The Mark II can launch 1.4-kilogram (three-pound) paint-filled cannonballs at a gut-punching 160 kilometres (100 miles) per hour, while its other arm sports a specially designed gun that launches paint rockets. The Megabot's creators explained, "We're Americans, so we've added really big guns." As the juggernauts take chunks out of each other, two brave pilots will be in the cockpit, controlling the Mark II's every move. The driver's view is almost fully obstructed by the robot's gunner, so an intricate camera system has been fitted to relay live video and help the driver see where they are going.

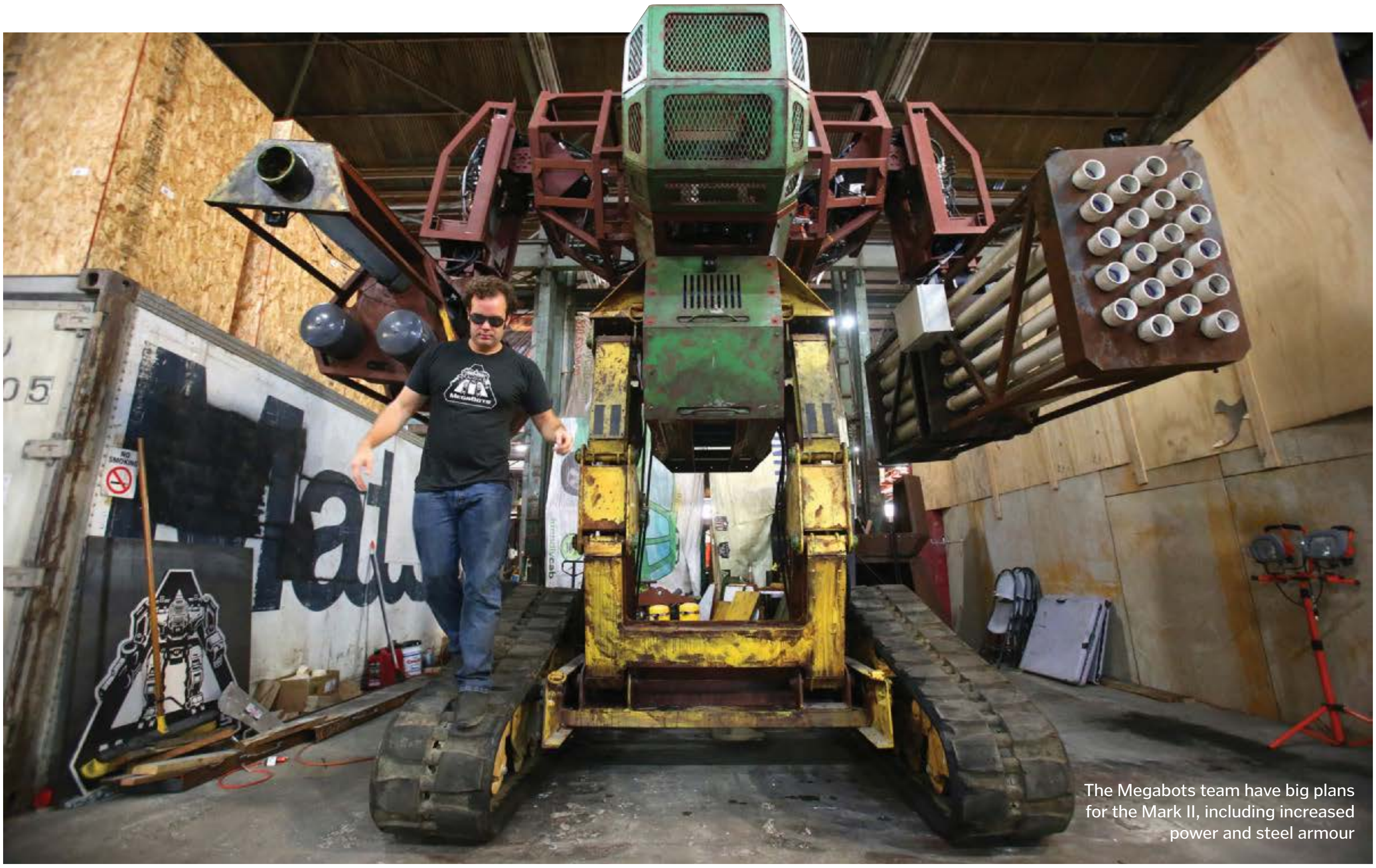
From the beginning of their project, the MegaBots team have had only one thing in mind: epic sports entertainment. Although the Mark II was a first for the US, it was not the first piloted humanoid to be created – a suitable opponent for the MegaBot already existed. Back in the summer of 2012, collaborators from Suidobashi Heavy Industry in Japan unveiled Kuratas, a four-metre (13-foot), single-pilot super-robot.

Despite being older than the Mark II, it's much more impressively equipped, with a superb heads-up display inside the cockpit and more advanced weaponry. One of its signature – if slightly sinister – features is the firing system for its 6,000 round per minute BB Gatling gun. Once the target is locked, the pilot can fire simply by smiling. Trigger-happy has a whole new meaning once you've seen Kuratas in action.

A particularly clever feature of Kuratas is that you don't need to be in the cockpit to operate it. Thanks to the clever V-Sido operating system, you can control the humanoid with any internet-enabled phone, which the designers call the 'Master Slave system'. At the moment this technology only works to control the robot's movement, but could be capable of firing its weapons in the future.

Incredibly, anyone can buy a fully-fledged version of Kuratas right now. It's probably the coolest thing for sale on Amazon Japan, but a fully customisable version will set you back over £650,000 ($990,000). Although the majority of us don't have that kind of cash to splash on humanoid robots, it does go to show that they have arrived, and they're here to stay.

When inventor Kogoro Kuratas received the challenge from the American team, he was quick to accept. Giant robots are a very real part of Japanese culture, and the team are not about to let the Americans defeat them. The duel will take place in June 2016, in a neutral location that's yet to be decided. The two challenge videos have received over ten million YouTube views between them, so there is definitely enough interest to make this battle truly epic. The sport of the future is here, and it's straight out of science fiction.



The Megabots team have big plans for the Mark II, including increased power and steel armour

Coming soon: Mark II upgrades

With less than a year to go, see how the MegaBots team plan to defeat their Japanese rivals

The designers of the Mark II recognise that they are a number of megabot-sized steps behind Kuratas. To help fund the necessary improvements, they have launched a Kickstarter campaign, in which they detail their plans to create a robot capable of handling anything Kuratas can throw at it. The power unit will be extensively upgraded, giving the Mark II five times its current horsepower, enabling it to cope with the demands of a heavier, energy-sapping frame.

Shock-mounted, steel armour will cover the majority of the Mark II's body, enabling it to withstand considerable punishment from the five-ton-punching Kuratas. The current track base mobility system tops out at a measly four kilometres (2.5 miles) per hour; MegaBots plans to introduce a new, five times faster system designed by Howe and Howe Technology, who have designed similar systems for the vehicles seen in Hollywood blockbusters *Mad Max: Fury Road* and *G.I. Joe: Retaliation*.

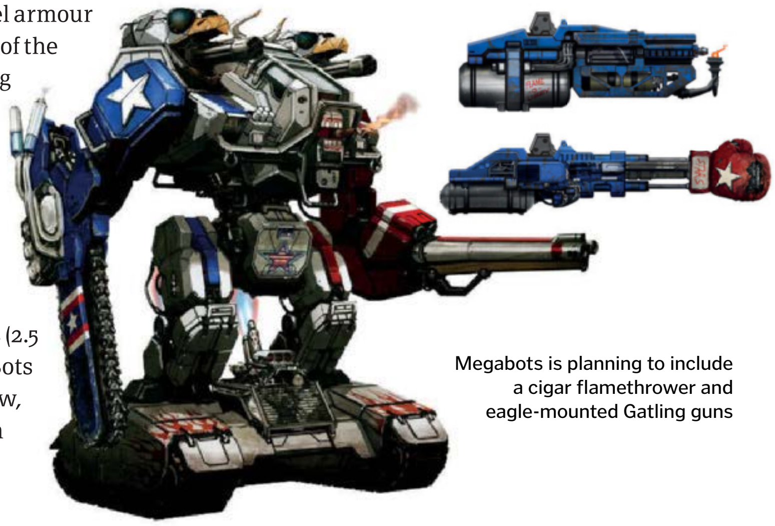
At the moment the Mark II is very top heavy, and risks toppling over should it take a punch or dish out a particularly powerful one itself. MegaBots is hoping to team up with IHMC Robotics, who specialise in robotic balance and control, making them the ideal company to design a custom system for the Mark II to ensure the robot stays upright no matter what happens.

If the Kickstarter campaign raises £800,000 ($1.25 million), MegaBots will seek help from NASA to improve their current cockpit safety system. This will help the robot fight more aggressively without endangering the pilot and gunner inside.

As the creators of Kuratas have demanded that the duel involves hand-to-hand 'melee' style combat, the Mark II will need to be fitted with appropriate weaponry. No one really knows what will work at this scale, but options include crushing and grasping claws, shields and pneumatically-driven fists.

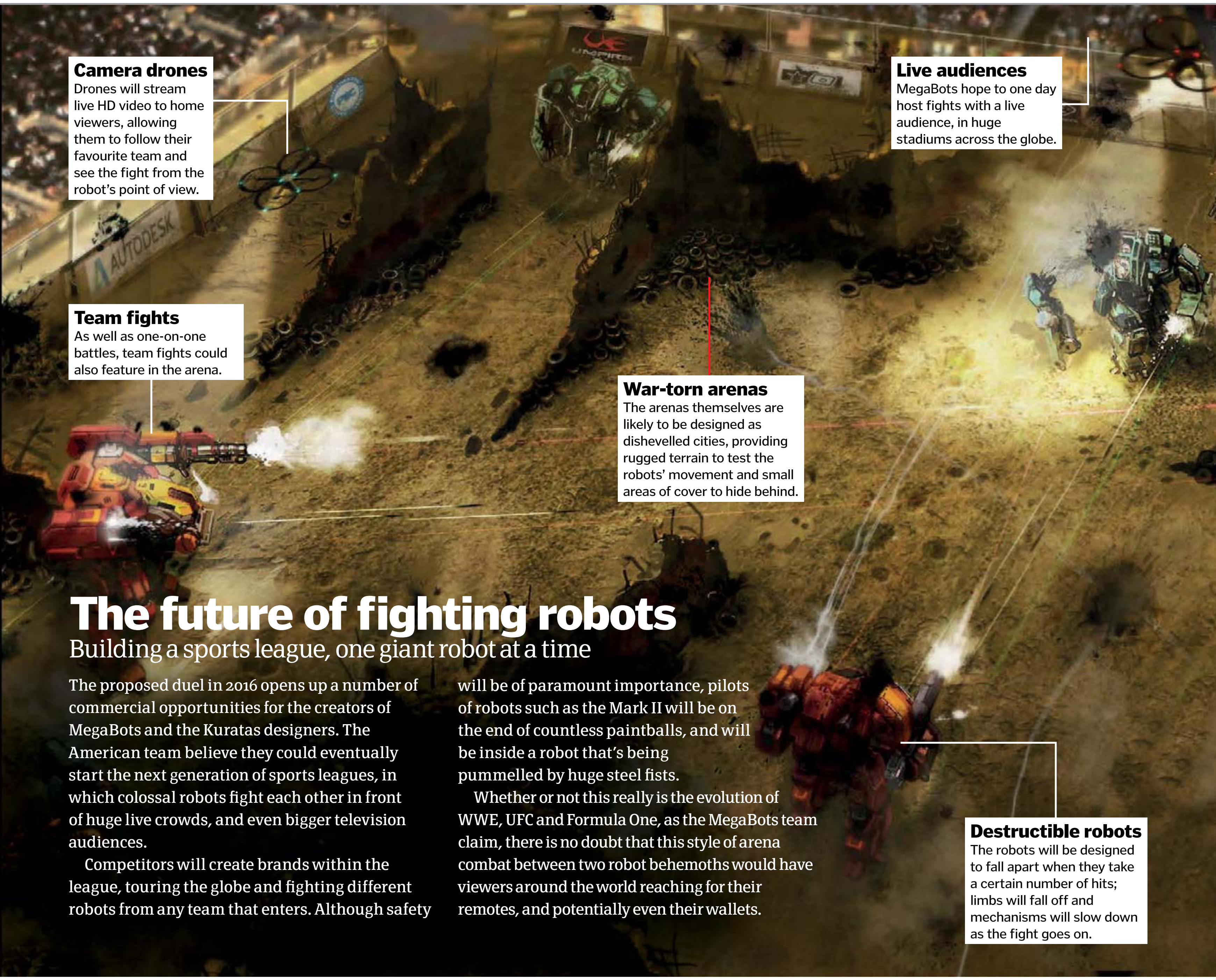
The designers themselves have said they would like to incorporate a giant chainsaw and shoulder-mounted Gatling guns, which fire out of eagle heads. Whichever combination of these gets the go-ahead, watching two giant robots knock the life out of each other will be quite a spectacle.

It is worth mentioning that no details have been released relating to the upgrades that the Kuratas team are planning. The Japanese are keeping their cards close to their chest, but if the current model is anything to go by, they will be mightily impressive.



Megabots is planning to include a cigar flamethrower and eagle-mounted Gatling guns

DID YOU KNOW? *If MegaBots secures £980,000 ($1.5 million) of funding, they will give the Mark II a Hollywood-grade paint job*



Camera drones
Drones will stream live HD video to home viewers, allowing them to follow their favourite team and see the fight from the robot's point of view.

Live audiences
MegaBots hope to one day host fights with a live audience, in huge stadiums across the globe.

Team fights
As well as one-on-one battles, team fights could also feature in the arena.

War-torn arenas
The arenas themselves are likely to be designed as dishevelled cities, providing rugged terrain to test the robots' movement and small areas of cover to hide behind.

Destructible robots
The robots will be designed to fall apart when they take a certain number of hits; limbs will fall off and mechanisms will slow down as the fight goes on.

The future of fighting robots

Building a sports league, one giant robot at a time

The proposed duel in 2016 opens up a number of commercial opportunities for the creators of MegaBots and the Kuratas designers. The American team believe they could eventually start the next generation of sports leagues, in which colossal robots fight each other in front of huge live crowds, and even bigger television audiences.

Competitors will create brands within the league, touring the globe and fighting different robots from any team that enters. Although safety will be of paramount importance, pilots of robots such as the Mark II will be on the end of countless paintballs, and will be inside a robot that's being pummelled by huge steel fists.

Whether or not this really is the evolution of WWE, UFC and Formula One, as the MegaBots team claim, there is no doubt that this style of arena combat between two robot behemoths would have viewers around the world reaching for their remotes, and potentially even their wallets.

The tech behind the robots

Although both the MegaBot Mark II and Kuratas are piloted robots, they both require their own operating system to allow for effective human control. Kuratas uses V-Sido OS, which was designed by the project's head roboticist, Wataru Yoshizaki. In terms of functionality, this software can be compared to the flight control systems, also known as avionics, present in all modern aircraft, as it handles all of the low level tasks while letting the pilot focus on high level commands. Specifically, V-Sido OS integrates routines for balance and movement, helping it to correct posture and prevent the robot from falling over if it is hit during combat or travels over a particularly uneven surface.

The MegaBot Mark II uses Robot OS, an operating system that gives users a flexible framework for writing their own robot software, and is essentially a collection of tools, conventions and libraries that aim to simplify the unenviable task of coding a giant robot. It can be adapted for any mission, making it ideal for MegaBots as they aren't entirely sure how their robot will complete simple undertakings, such as walking and maintaining its balance.

As robotics continue to develop, operating systems will be refined and improved. If robotics advances at the same rate as personal computing has done in the last 20 years, it won't be long before robots are commonplace in both our homes and the workplace.

© Corbis

Bladeless fans

How can a circle with no moving parts create a breeze?

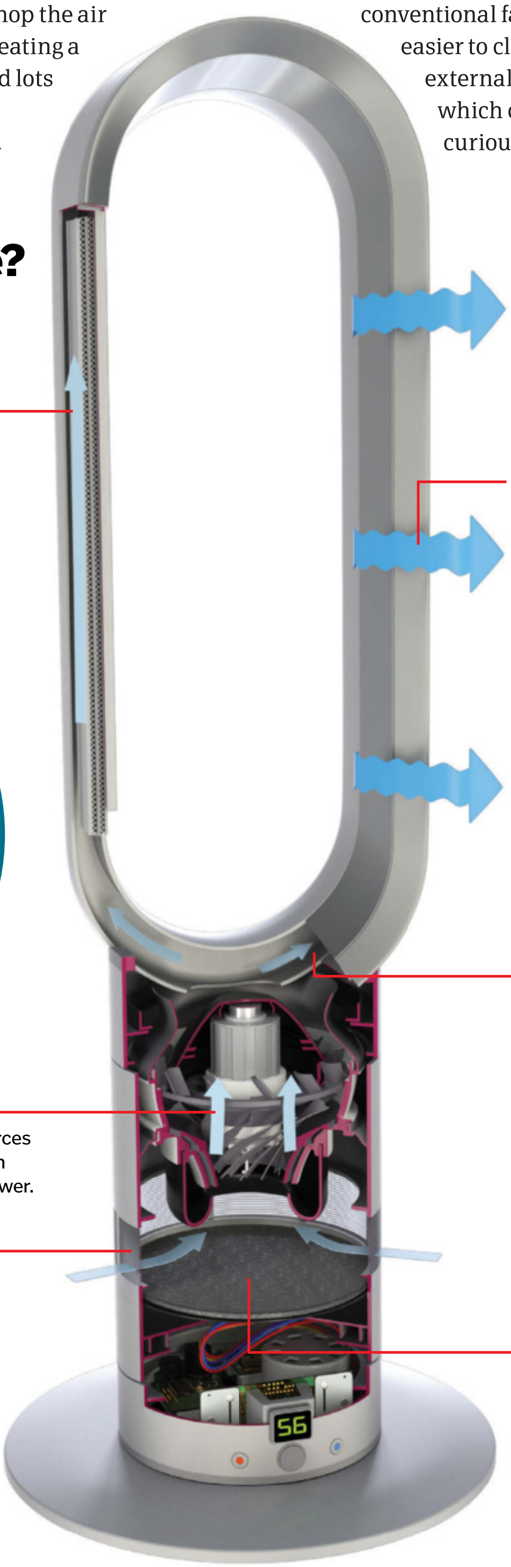
Despite appearances, a bladeless fan does actually have a small, concealed fan inside its main body. The way it uses this to produce a stream of cool air is very different from normal models, though.

A traditional fan's blades chop the air as it is sent towards you, creating a rather turbulent breeze and lots of noise. A bladeless fan provides a much smoother, constant stream of air which will gently, and quietly, cool you down.

Other than the airflow itself, bladeless fans have several advantages. They are more energy efficient than air conditioning units or conventional fans, and are much easier to clean. They also lack external spinning blades, which can cause injury to curious children.

What's inside?

The secret behind the technology



Aerofoil propulsion
The air is shot through a 1.3mm (0.05in) slit, which speeds it up to 88.5km/h (55mph).

Quiet yet powerful
Large conventional fans are often powerful, but they are typically also very loud. The latest generation of bladeless fans are both quiet and forceful; you get the best of both worlds.

Amplified airflow
As the air jets out of the front of the fan, it draws extra air from behind and to the sides, amplifying the airflow by a process known as viscous shearing.

Impeller
The fan's mixed flow impeller forces the air to flow quickly and at high pressure, increasing the fan's power.

Air entry
Inside the fan's main body is an electric motor that sucks air in through small vents at its base, working like a vacuum cleaner in reverse.

Helmholtz cavity
This brilliantly designed housing captures and dissipates motor noise, helping to keep the fan as quiet as possible.

Bladeless fans are more energy-efficient than traditional models

Illustration by Nicholas Forder

Inside a hand dryer

You'll be blown away by the clever tech that dries our hands in seconds with high-speed jets of air

Most modern hand dryers contain a heating element that's activated either by the push of a button, or the triggering of an infrared motion sensor. The versions with infrared sensors are much more environmentally friendly, as they ensure that the dryer isn't left running unnecessarily once the user has left, saving both energy and money.

The heating element inside a hand dryer is made of Nichrome (an alloy of nickel and chromium) that heats passing air by up to 50 degrees Celsius (90 degrees Fahrenheit). Once the hot air has been created, it's quickly channelled through a pipe and expelled at high pressure onto your wet hands. The pressure of the air is enough to blow water directly off them, while the warmth dries out the moisture.

Concerns have been raised over whether or not hand dryers are hygienic. Modern versions have High Efficiency Particulate Air filters built in, to remove 99.97 per cent of disease-causing germs from the air they blast out. However, some studies have shown that dryers can blow bacteria from people's hands into the surroundings if they have not been washed properly.

Some hand dryers blow air towards you at over 640km/h (400mph)

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The Galapagos Islands

Nestled on the equator in the Eastern Pacific are islands so special, they changed our natural history forever

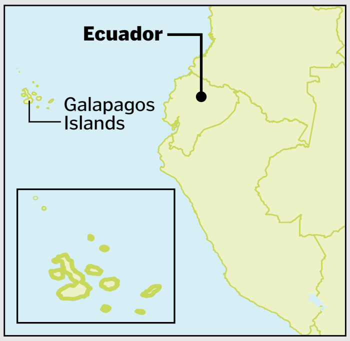
Found far off the coast of continental Ecuador is an archipelago of 13 main islands, along with many other rocks and islets that form one of the most extraordinary ecosystems on Earth. Famous for spurring on Charles Darwin to develop his game-changing theories of evolution and natural selection, the rocky ocean outcrops of the Galapagos Islands were first discovered in 1535 by the Bishop of Panama. He was on his way to Peru when his ship was carried to the islands by currents. There started a long history of the islands' use by pirates, whalers and sailors alike, before Darwin made his famous visit on the HMS Beagle in 1835. Today, the main islands support around 25,000 people in communities on Santa Cruz, San Cristobal, Isabela and Floreana.

Much like Hawaii, the Galapagos Islands were formed by volcanic activity. Situated above a tectonic hotspot, giant plumes of molten rock from the Earth's core forced their way to the surface, sputtering upwards and solidifying in layers through the water. Over time, the new rock finally broke the surface, and so the Galapagos Islands were born. And they aren't finished forming yet, as volcanoes on the youngest island still erupt. The most recent was in 2009, when La Cumbre Volcano on Isla Fernandina blew on April 11, releasing pahoehoe lava flows and giant swathes of volcanic ash.

Beneath the sea, the volcanic island chain continues for hundreds of miles, where the underwater islands that failed to break the surface provide shelter for countless marine species. The exact location of this archipelago in the Pacific means that the Galapagos benefits from the confluence of three major ocean currents: the warm Panama current, the deep-sea Cromwell current and the cold Humboldt current. Where deep-sea currents collide, there are areas of nutrient upwelling, which produces a fertile boom of life and forms the base of the entire island food chain. This happens in abundance around the Galapagos, bringing oceanic visitors from far and wide to enjoy the bountiful buffet delivered by the currents. And where the oceans are teeming with unique species, life on land follows suit.

One of the most fascinating things about these islands is the astounding array of plants and animals that live there. Unique species call the islands home – creatures that cannot be found anywhere else in the world. Giant tortoises, marine iguanas and flightless cormorants are all local favourites, not to mention the Galapagos penguins – the only

On the map



The animals of the Galapagos are surprisingly tame, having never needed to fear humans

DID YOU KNOW? *'Galapagos' is an old Spanish word for saddle, originally used to describe the shells of giant tortoises*

penguins to be found north of the equator. What is more amazing is that each island has its own completely separate subspecies of many of these creatures. The region has one of the highest levels of endemism in the world, making the islands incredibly fascinating for scientists to study.

But how does an island chain so extremely isolated in the middle of the Pacific, 966 kilometres (600 miles) from continental Ecuador, bloom into an oasis of life? The answer, once again, lies in the sea. The archipelago is found along the equator; couple this with the presence of the cool Humboldt and Cromwell ocean currents and this allows the islands to display both tropical and temperate climates, a property that is mirrored by the array of animals living on the islands.

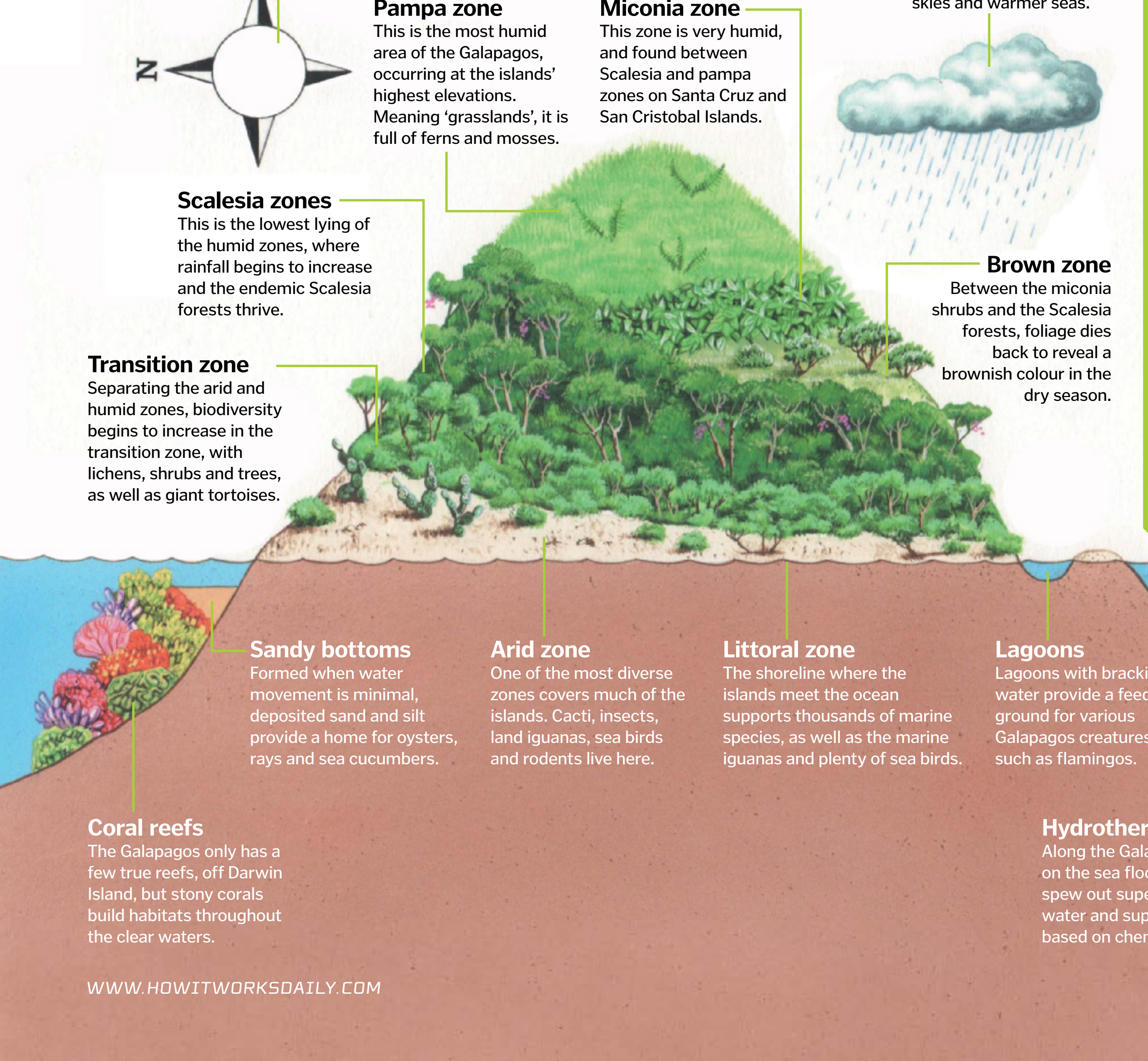
Yet although the wildlife is bountiful, it's also rather unevenly balanced. There are lots of reptiles such as marine and land iguanas, but no amphibians; plenty of birds including the blue-footed booby and waved albatross, but few mammals save for a handful of species including the Galapagos sea lions. There are also lots of grasses and ferns, but a distinct shortage of flowering or seeding plants.

This is a direct reflection of how Galapagos was populated by life. Plants and animals had to find their way there by chance, which can happen two ways: by air or by sea. Grasses and ferns have much lighter seeds that can be blown in the wind, and seabirds simply fly there (bringing hitch-hikers with them on feathers or in their guts)! Those that arrived by sea are hypothesised to have travelled on makeshift craft – such as rats on rafts of floating debris – bringing in hardy, salt-tolerant seeds from coastal plants on the mainland.

Because of these incredible creatures, the Galapagos Islands became an Ecuadorian national park in 1959 and was declared a UNESCO World Heritage Site in 1978. Due to the amazing marine life that lives in and visits the surrounding waters of the archipelago, the area was declared a biological marine reserve in 1986, and in 1990 the Galapagos waters also became a whale sanctuary.

Galapagos habitats

The distinct environmental factors of this archipelago provide plenty of complex habitat variations



Dry season
From July to December, the southern trade winds bring the cold Humboldt current to the islands. The water is cooler, and the highlands are shrouded in mist, while the rest is dry.

Southern winds
Trade winds blowing from south to north combined with ocean currents help to regulate the climate.

Warm season
January to June is the warm season – the climate is more tropical with daily rain, cloudier skies and warmer seas.

Pampa zone
This is the most humid area of the Galapagos, occurring at the islands' highest elevations. Meaning 'grasslands', it is full of ferns and mosses.

Miconia zone
This zone is very humid, and found between Scalesia and pampa zones on Santa Cruz and San Cristobal Islands.

Scalesia zones
This is the lowest lying of the humid zones, where rainfall begins to increase and the endemic Scalesia forests thrive.

Brown zone
Between the miconia shrubs and the Scalesia forests, foliage dies back to reveal a brownish colour in the dry season.

Transition zone
Separating the arid and humid zones, biodiversity begins to increase in the transition zone, with lichens, shrubs and trees, as well as giant tortoises.

Sandy bottoms
Formed when water movement is minimal, deposited sand and silt provide a home for oysters, rays and sea cucumbers.

Arid zone
One of the most diverse zones covers much of the islands. Cacti, insects, land iguanas, sea birds and rodents live here.

Littoral zone
The shoreline where the islands meet the ocean supports thousands of marine species, as well as the marine iguanas and plenty of sea birds.

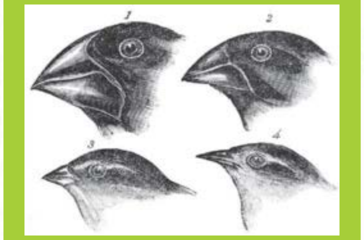
Lagoons
Lagoons with brackish water provide a feeding ground for various Galapagos creatures, such as flamingos.

Coral reefs
The Galapagos only has a few true reefs, off Darwin Island, but stony corals build habitats throughout the clear waters.

Hydrothermal vents
Along the Galapagos Rift on the sea floor, vents spew out super-heated water and support life based on chemosynthesis.

The islands and Charles Darwin

The Galapagos Islands are famously linked to Charles Darwin, and his groundbreaking theory of evolution. Darwin visited the chain of islands in 1835 on the second voyage of the HMS Beagle, where he explored numerous islands and was captivated by the extraordinary biodiversity. Although he took a great many notes, it wasn't until he returned to Britain that he came to thinking about how the species on each island had developed. He compiled his journals and sketches alongside those of this fellow travellers and then two years after the Beagle's return he began to develop his theories of evolution and natural selection. His monumental book *On The Origin Of Species* was published in 1859.



Darwin speculated that Galapagos finches evolved from a common ancestor and adapted to their habitats

Galapagos flora and fauna

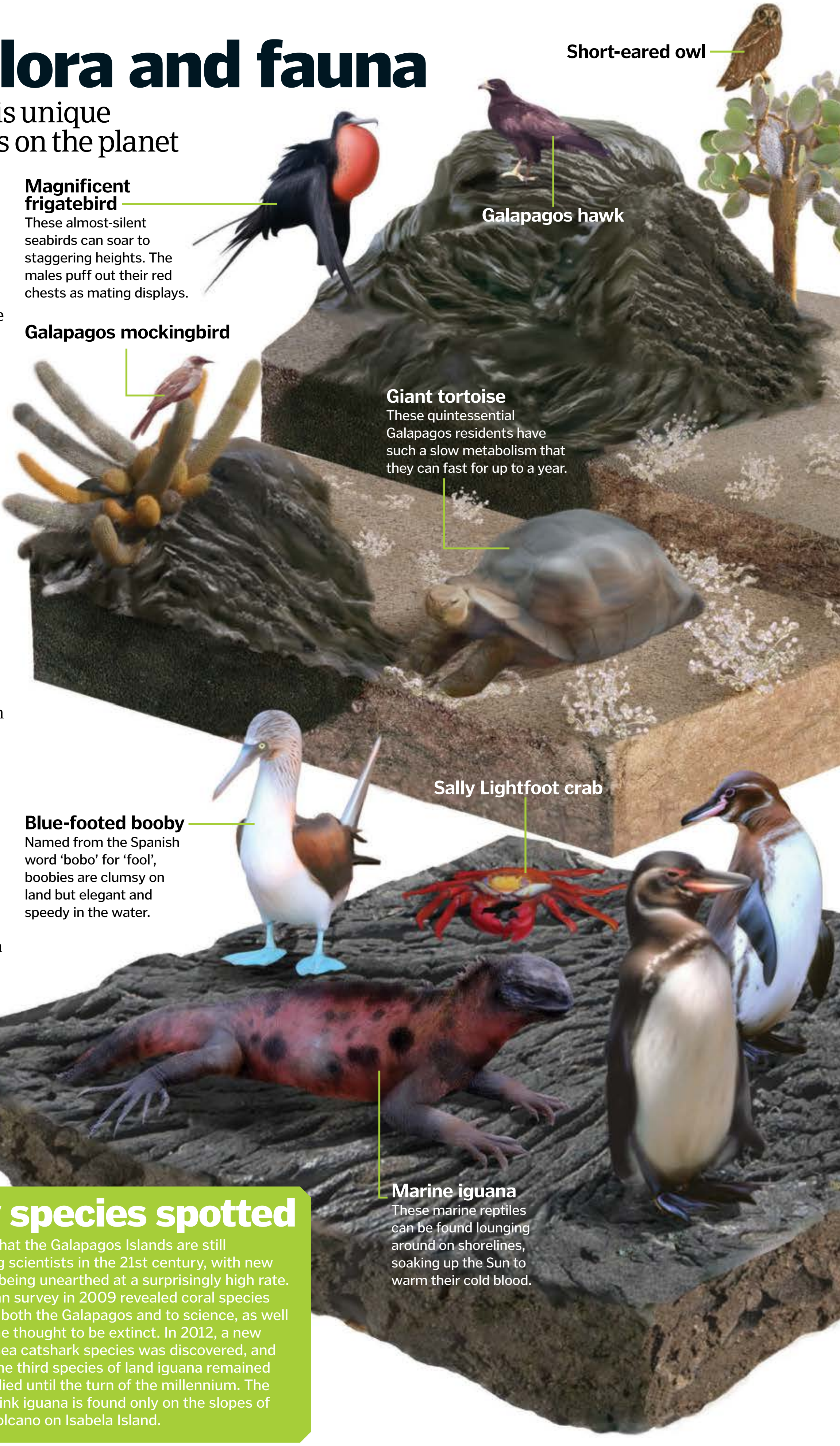
The plants and animals of this unique archipelago are like no others on the planet

The Galapagos is an ecosystem populated by incredible living things. Probably the most well-known creatures that call these islands home are the giant Galapagos tortoises – huge reptiles that can reach up to 1.5 metres (five feet) in length and live for over 100 years!

Each island is home to a distinct giant tortoise species, and there are approximately 14 known members of their genus. Their populations suffered after being hunted by whalers, pirates and sailors, and the introduction of new animals to the islands led to increased predation and competition for food. Perhaps one of the most famous Galapagos inhabitants was Lonesome George – the last Pinto Island tortoise – who died in 2012, marking the extinction of his species.

Another of the Galapagos' superstar species is the marine iguana, also exclusive to this island chain. Despite their fearsome appearance, the iguanas are herbivorous. They are the only kind of iguana to use their long, flattened tails to propel them through the saltwater to feed on algae and seaweed beneath the waves.

The islands have been designated as a national park and conservation area to protect their incredible species diversity; approximately 80 per cent of land birds and 97 per cent of reptiles and land mammals found there are endemic. The waters around the islands are also a protected marine reserve, and the list of unique species doesn't stop on land. The reserve protects over 50 species of fish that are only found in that location. It's a haven for sea turtles and even a whale sanctuary to protect the larger ocean visitors.

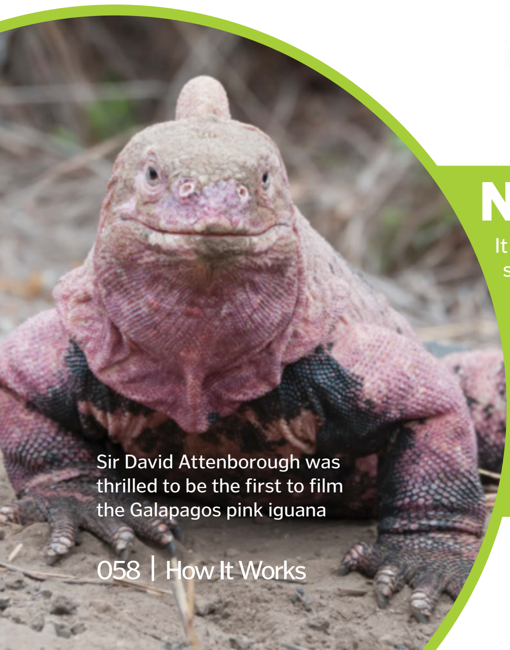


Magnificent frigatebird
These almost-silent seabirds can soar to staggering heights. The males puff out their red chests as mating displays.

Giant tortoise
These quintessential Galapagos residents have such a slow metabolism that they can fast for up to a year.

Blue-footed booby
Named from the Spanish word 'bobo' for 'fool', boobies are clumsy on land but elegant and speedy in the water.

Marine iguana
These marine reptiles can be found lounging around on shorelines, soaking up the Sun to warm their cold blood.

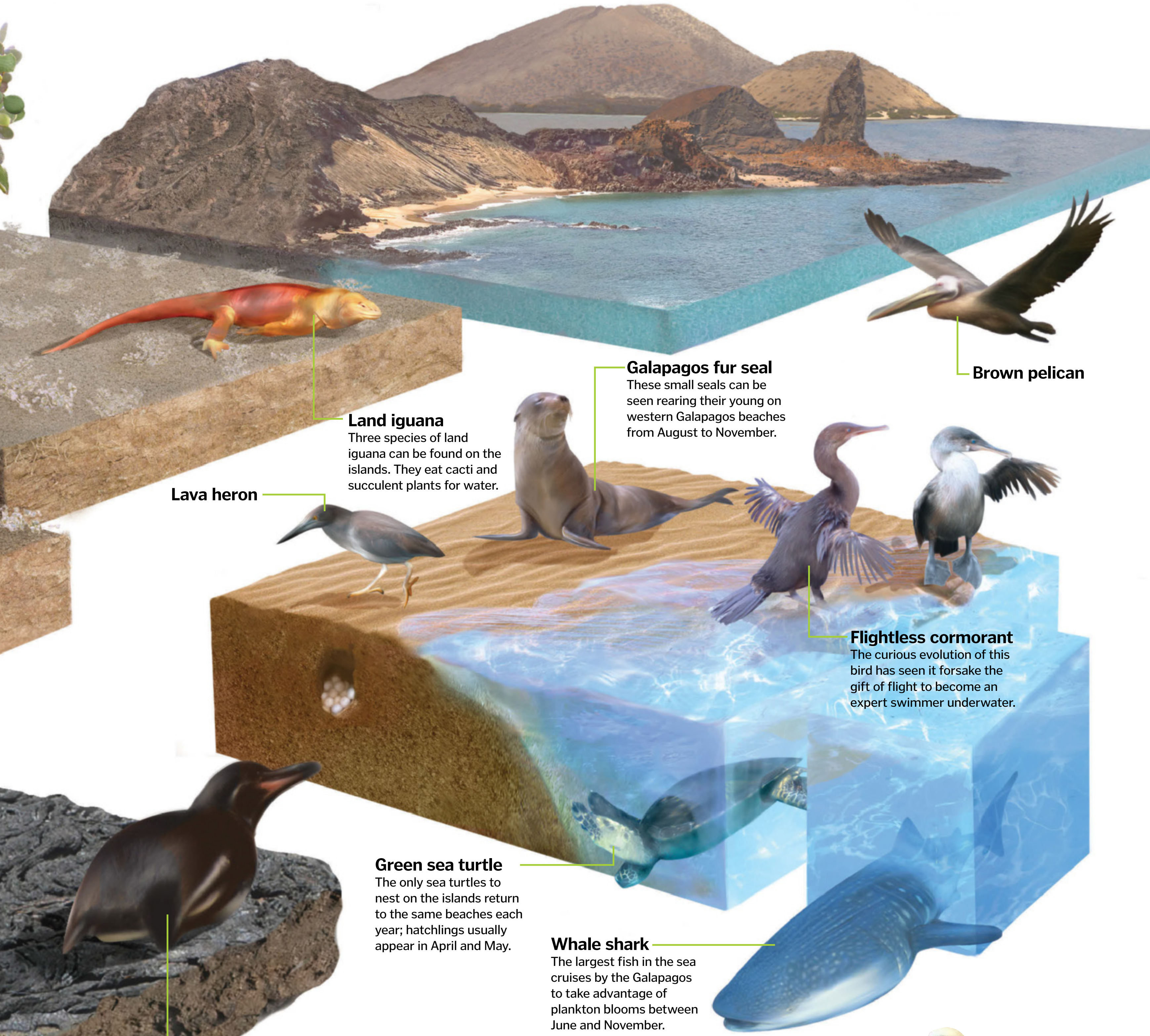


Sir David Attenborough was thrilled to be the first to film the Galapagos pink iguana

New species spotted

It seems that the Galapagos Islands are still surprising scientists in the 21st century, with new species being unearthed at a surprisingly high rate. An ocean survey in 2009 revealed coral species new to both the Galapagos and to science, as well as some thought to be extinct. In 2012, a new deep-sea catshark species was discovered, and even the third species of land iguana remained unstudied until the turn of the millennium. The huge pink iguana is found only on the slopes of Wolf Volcano on Isabela Island.

DID YOU KNOW? *Marine iguanas sneeze out excess salt from their bodies, leaving distinctive white patches on their heads*



Galapagos fur seal
These small seals can be seen rearing their young on western Galapagos beaches from August to November.

Brown pelican

Land iguana
Three species of land iguana can be found on the islands. They eat cacti and succulent plants for water.

Lava heron

Flightless cormorant
The curious evolution of this bird has seen it forsake the gift of flight to become an expert swimmer underwater.

Green sea turtle
The only sea turtles to nest on the islands return to the same beaches each year; hatchlings usually appear in April and May.

Whale shark
The largest fish in the sea cruises by the Galapagos to take advantage of plankton blooms between June and November.

Galapagos penguin
It's thought that these penguins travelled to the Galapagos on the Humboldt current, which brings cold water north from Antarctica.

Threats & conservation

The delicate Galapagos ecosystem has been vulnerable to numerous threats in the past, such as invasive species arriving and outcompeting the natives for food and space (goats and fire ants are particularly destructive), illegal fishing and human overpopulation. To tackle these issues, the various charities and foundations that look after the islands, such as the Galapagos National Park and the Charles Darwin Foundation have laid out plans for ecosystem management as well as education, to allow communities of the Galapagos to be involved in the protection of their island home.

Populations of waved albatrosses are closely monitored

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How do plants grow towards light?

A hormone makes sure the plant has enough sunlight to survive

Plants depend on a process called photosynthesis to make their own food. This converts water from the soil and carbon dioxide in the air into oxygen and glucose (sugar). Sunlight is crucial for this chemical change and without it, green plants are unable to survive.

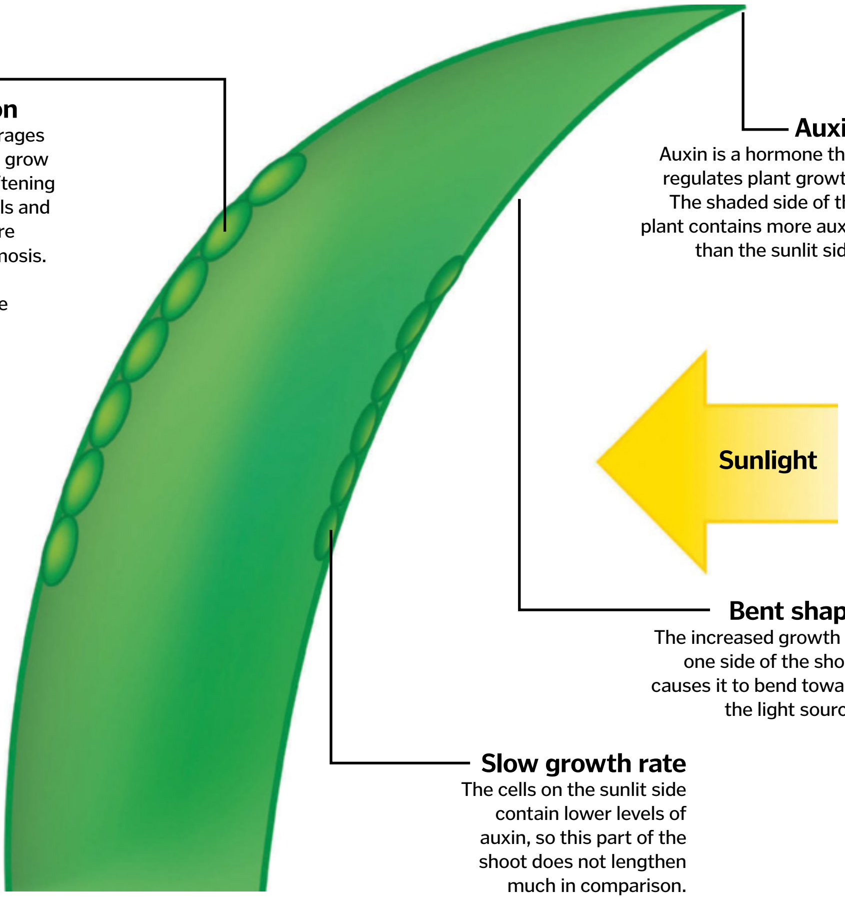
Plant cells contain a protein called phototropin, which is activated when it absorbs the blue wavelength of light. This leads to an uneven distribution of the hormone auxin (which regulates growth) in the stem. The exact mechanisms behind this process are not fully understood, but one theory is that sunlight destroys or inhibits auxin so the hormone levels on the Sun-facing side reduce. Another theory is that auxin molecules are able to move from cell to cell across the stem, away from the area where light was detected by the phototropins. Auxin causes cells to enlarge, so the shaded side of the stem – which contains higher levels of the hormone – elongates, forcing the plant to bend towards the light as a result.

Sunflowers take their quest for sunlight to the extreme. These plants follow the Sun throughout the day, physically rotating their leaves and flowers to make the most of the available light. At night they then unwind, returning to their starting position ready for sunrise. No one knows why the flowers follow the Sun as well as the leaves, although it's thought the extra heat may help to grow more seeds.

Sunflowers follow the Sun's rays throughout each day by rotating their leaves and flowers

Phototropism

With the help of the hormone auxin, plants can get as much light as possible



Cell elongation
Auxin encourages plant cells to grow in size by softening their cell walls and taking in more water by osmosis. This in turn elongates the shaded side.

Auxin
Auxin is a hormone that regulates plant growth. The shaded side of the plant contains more auxin than the sunlit side.

Bent shape
The increased growth of one side of the shoot causes it to bend toward the light source.

Slow growth rate
The cells on the sunlit side contain lower levels of auxin, so this part of the shoot does not lengthen much in comparison.

Killer plants

Not satisfied with making food through photosynthesis, these five carnivorous plants capture, kill and eat living prey

Drosera
There are over 100 species of drosera, which are commonly known as 'sundews' as they appear to be constantly covered in dew. These tiny droplets are actually sticky enzymes that trap and start to digest prey as soon as it lands on the plants' leaves.

Venus flytrap
When an insect or arachnid steps on more than one of the tiny hairs of the plant's jaws, it triggers a violent reaction. The hinged mouth snaps down, trapping the prey inside the plant. Digestive enzymes are secreted and it can be several days until the plant re-opens.

Nepenthes
These plants lure insects, and sometimes even rats, into their cup-like pitchers with an attractive scent. Once trapped, the prey drowns in the liquid within the pitcher and is broken down by digestive juices, allowing the plant to absorb the vital nutrients it needs to survive.

Pinguicula
This plant catches prey using sticky leaves. The tacky substance is actually full of digestive enzymes, which break down the insects once they become trapped. When winter arrives, some species of pinguicula become quite dormant and cease their carnivorous activities.

Sarracenia
Like Nepenthes, sarracenia is a pitcher plant. Insects are attracted to its colour and sweet scent. As they land at the edge of the pitcher, they often fall in, since the edge is very slippery. Once inside, there is no escape due to the smooth, steep sides of the pitcher.

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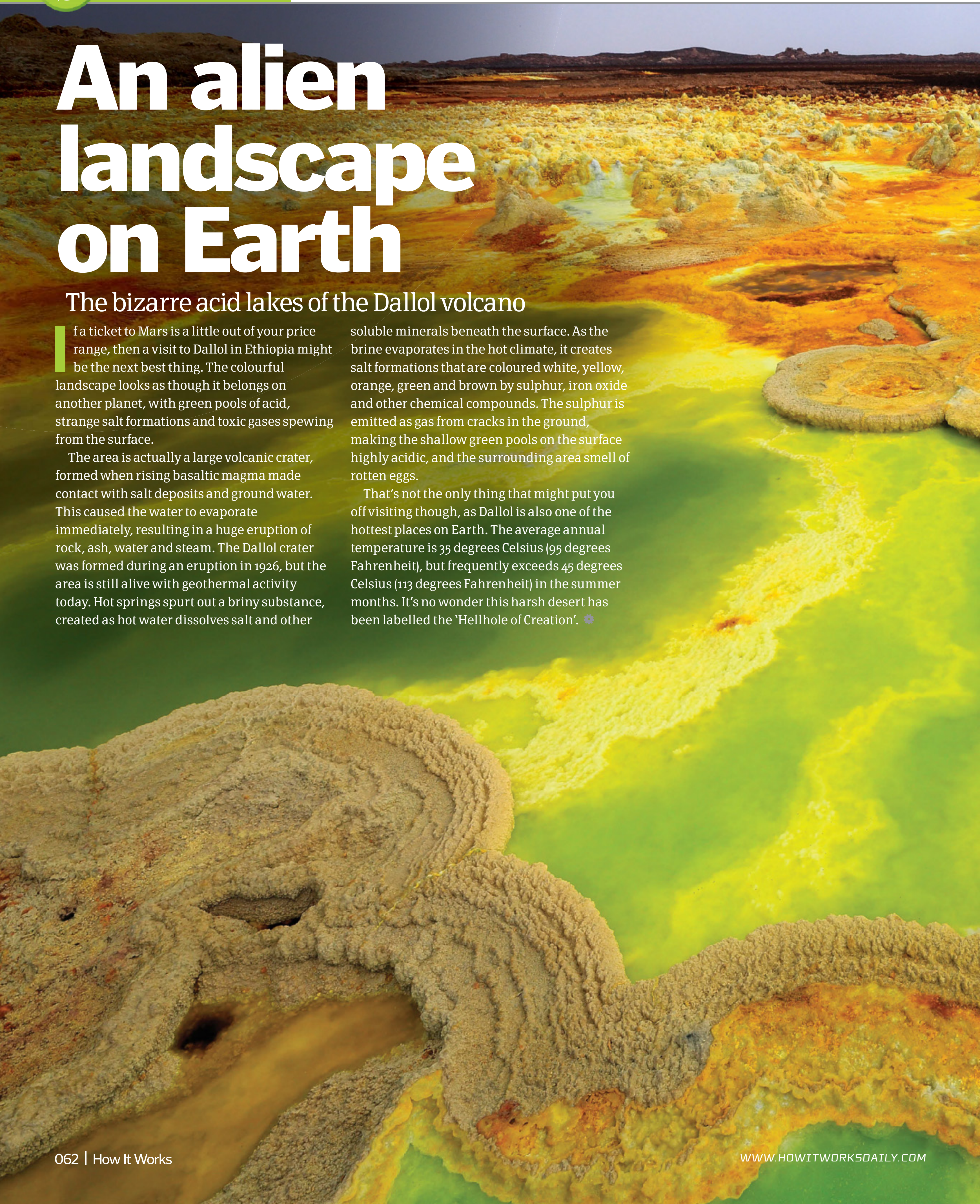


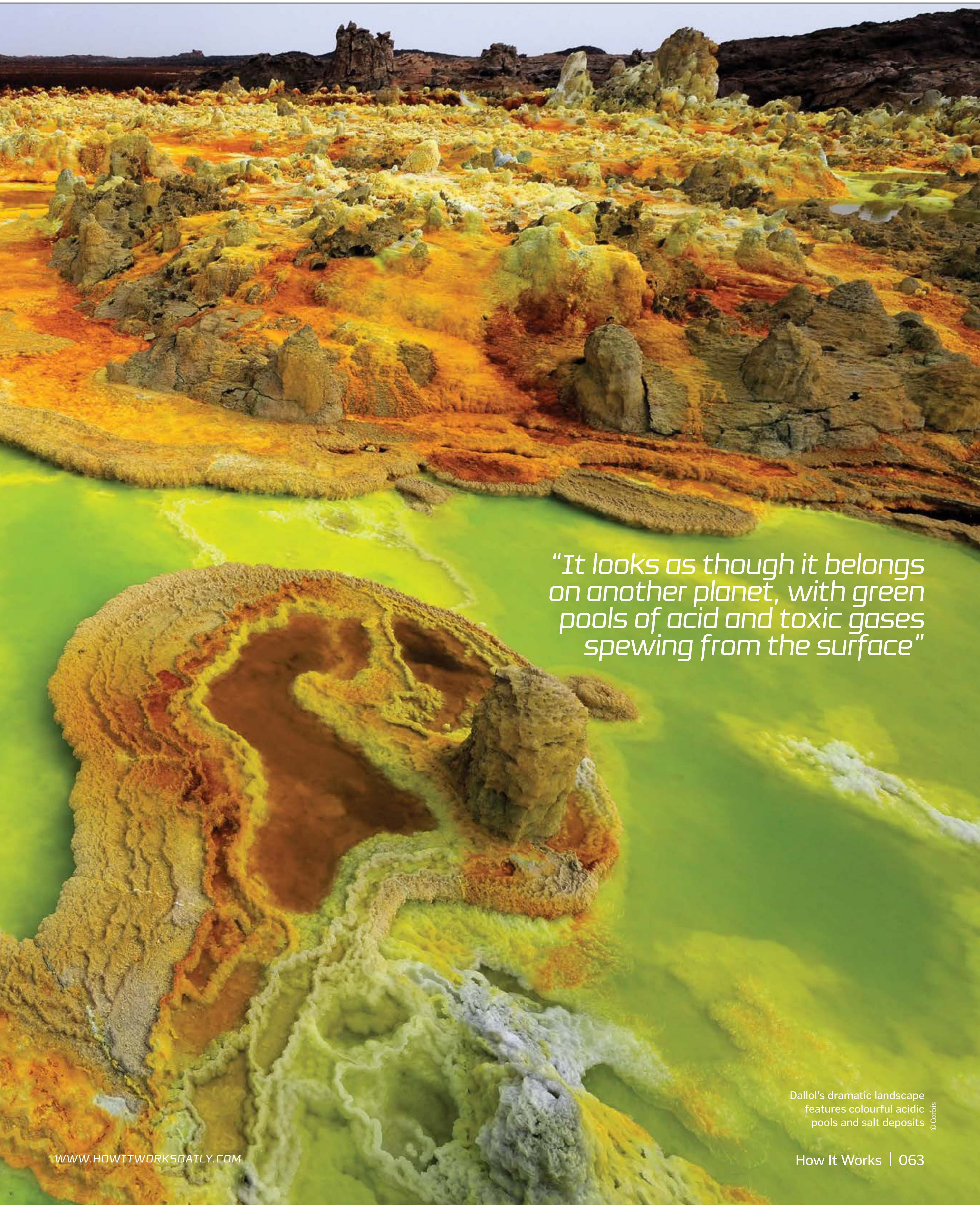
An alien landscape on Earth

The bizarre acid lakes of the Dallol volcano

If a ticket to Mars is a little out of your price range, then a visit to Dallol in Ethiopia might be the next best thing. The colourful landscape looks as though it belongs on another planet, with green pools of acid, strange salt formations and toxic gases spewing from the surface.

The area is actually a large volcanic crater, formed when rising basaltic magma made contact with salt deposits and ground water. This caused the water to evaporate immediately, resulting in a huge eruption of rock, ash, water and steam. The Dallol crater was formed during an eruption in 1926, but the area is still alive with geothermal activity today. Hot springs spurt out a briny substance, created as hot water dissolves salt and other soluble minerals beneath the surface. As the brine evaporates in the hot climate, it creates salt formations that are coloured white, yellow, orange, green and brown by sulphur, iron oxide and other chemical compounds. The sulphur is emitted as gas from cracks in the ground, making the shallow green pools on the surface highly acidic, and the surrounding area smell of rotten eggs.

That's not the only thing that might put you off visiting though, as Dallol is also one of the hottest places on Earth. The average annual temperature is 35 degrees Celsius (95 degrees Fahrenheit), but frequently exceeds 45 degrees Celsius (113 degrees Fahrenheit) in the summer months. It's no wonder this harsh desert has been labelled the 'Hellhole of Creation'.



"It looks as though it belongs on another planet, with green pools of acid and toxic gases spewing from the surface"

Dallol's dramatic landscape features colourful acidic pools and salt deposits

© Corbis

The life of an oyster

The bivalve molluscs that seem to have the best of both worlds

Oysters are amazing bivalve molluscs – sea creatures related to slugs and snails that live in hard, hinged shells. Considered a culinary delicacy and aphrodisiac, oysters live naturally in large colonies, called beds or reefs, throughout the world's oceans, as well as being farmed commercially. They feed by filtering plankton from the water column, and are considered to be 'ocean cleaners' due to their ability to filter gallons of water over their gills every day. Capable of living up to 20 years, these critters also have an incredible life cycle.

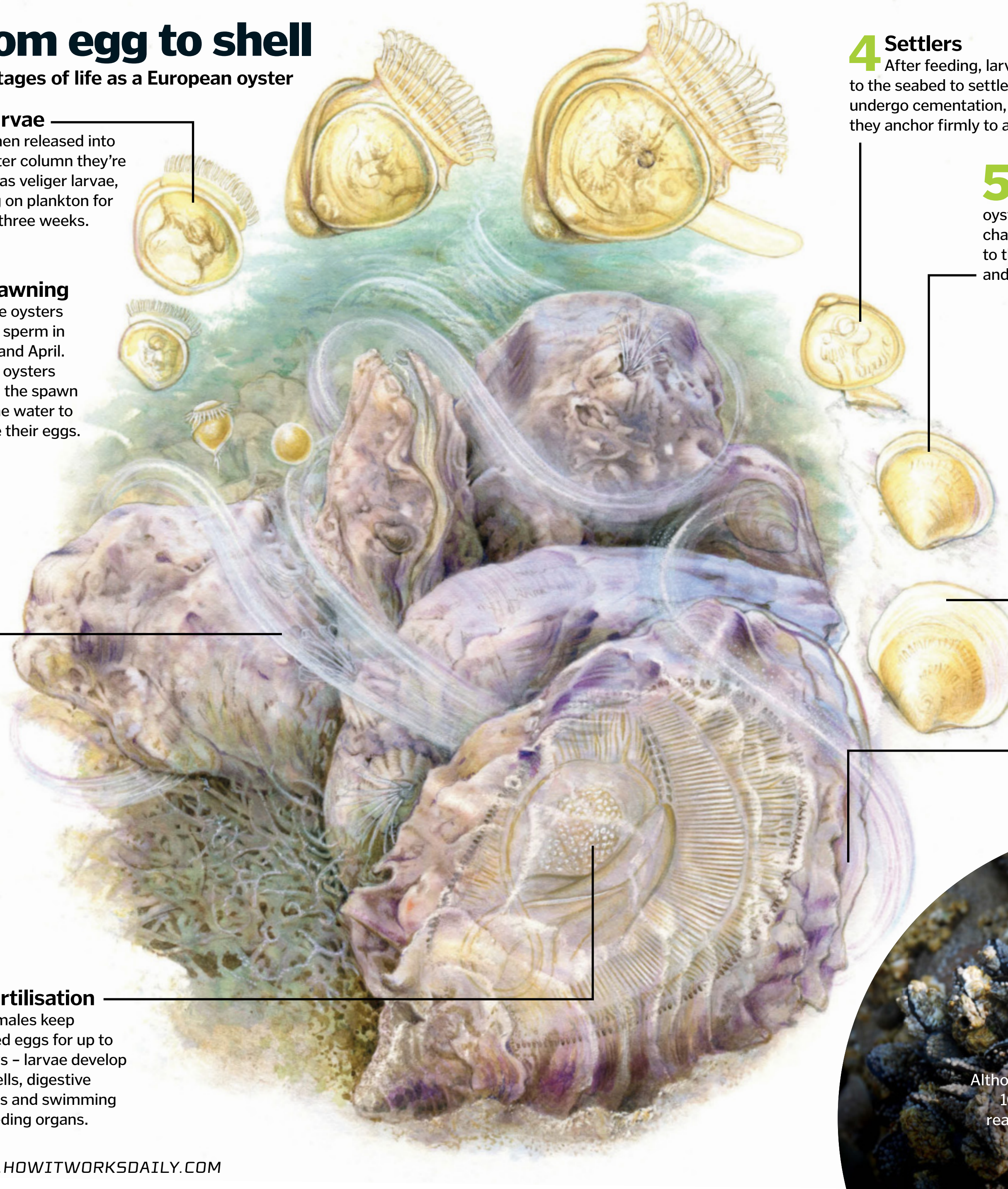
Oysters take cues from the environment in order to gauge the right time to spawn, but it usually takes place in the spring. When the temperature is at an optimum value (this varies depending on the oyster's specific location), the male oysters release sperm into the water, and the female oysters draw it in. Once their eggs are fertilised, they then release them into the water column to begin their journey.

The fertilised eggs grow as free-swimming larvae until it's time to settle. They then seek out a hard substrate to attach to, keeping them anchored as they mature.

One of the surprising things about oysters is that they are able to spawn as both male and female. All oysters settle and begin adult life as male, then after spawning once they switch sexes and develop as females to spawn again, this time with eggs rather than sperm. This phenomenon can happen twice in one season!

From egg to shell

The stages of life as a European oyster



1 Spawning Male oysters release sperm in March and April. Female oysters draw in the spawn from the water to fertilise their eggs.

2 Fertilisation Females keep fertilised eggs for up to ten days – larvae develop tiny shells, digestive systems and swimming and feeding organs.

3 Larvae When released into the water column they're known as veliger larvae, feeding on plankton for two to three weeks.

4 Settlers After feeding, larvae sink to the seabed to settle and undergo cementation, where they anchor firmly to a rock.

5 Metamorphosis Settled juvenile oysters undergo rapid change, where they adjust to their new surroundings and begin their sessile life.

6 Spats The juvenile oysters, known as spats, draw in water through their gills and filter plankton to eat, providing sustenance for quick growth.

7 Maturity As 'protandric hermaphrodites', oysters mature after four years as males, then after spawning they become female and produce eggs.

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Although usually measuring around 10cm (3.9in), some oysters can reach over 30cm (11.8in) or more

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The Moon is shrinking!

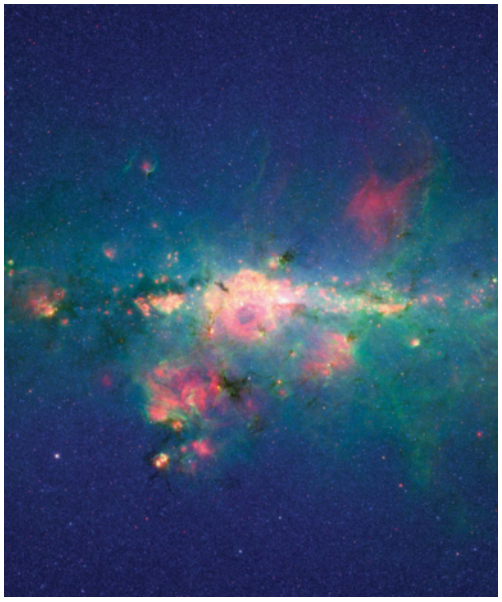
Plus nine more out-of-this-world facts explained

1 The Milky Way smells of rum and tastes like raspberries

This unlikely discovery was made by astronomers studying interstellar objects for new molecules. They had the IRAM radio telescope trained on Sagittarius B2 – a gas cloud at the centre of the Milky Way galaxy – when they found a chemical called ethyl formate. This is one of the aroma compounds that creates the sweet scents of fruit, wine and flowers, and it smells a lot like rum. It is also the chemical that gives raspberries their distinctive flavour.

Ethyl formate is made from ethanol – a common molecule found in star-forming gas clouds – with formic acid, which is a mix of hydrogen, oxygen and carbon atoms. It's visible to radio telescopes because ethyl formate molecules absorb the radiation from the stars and re-radiate it at radio wavelengths. Ethyl formate molecules are some of the largest molecules ever found in space and are among the building blocks of amino acids, which are vital for life as we know it.

Even though Sagittarius B2 is extremely dense as far as star-forming regions go, it still only has around 3,000 molecules per cubic centimetre, compared to around 25 million trillion molecules per cubic centimetre in the air that we breathe on Earth. So, even if you could breath in the nebula, it would sadly be too rarefied to actually smell the rum or taste the raspberries.



DID YOU KNOW? *There are around 200 billion stars in the Milky Way alone, the majority of which are red dwarf stars*

2 There's a planet with a tail

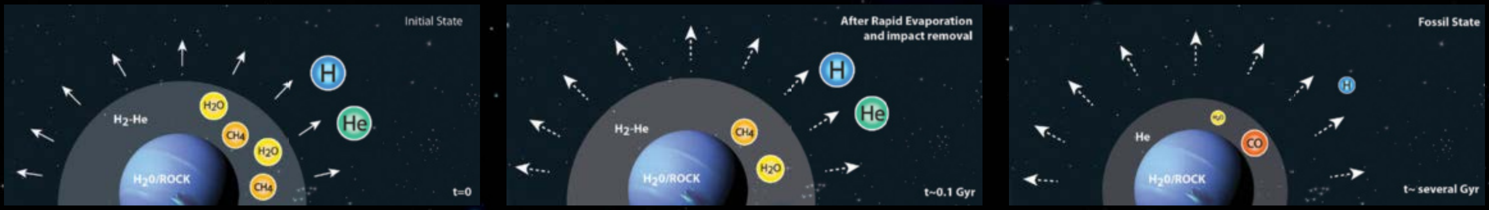
Some exoplanets are just bizarre, and none more so than Gliese 436b. It's what astronomers call a hot-Neptune – a Neptune-sized world that is extremely close to its star and therefore is very hot. What makes Gliese 436b – which is about 33 light years away – even weirder is its tail, which resembles that of a comet.

The planet has a thick gaseous hydrogen atmosphere, but since it orbits a mere 4 million kilometres (2.5 million miles) away from its parent star, this atmosphere is evaporating due to stellar radiation. The resulting cloud of dispersed hydrogen creates a huge comet-like tail that trails behind the exoplanet as it speeds around the star, completing an entire orbit in just 2.6 Earth days. Scientists estimate that Gliese 436b has lost as much as ten per cent of its atmosphere during its lifetime. It also shed hydrogen at a much greater rate in the past, while its star was more active.

An artist's impression of the huge trail of water vapour streaming away from Gliese 436b

How a planet can sprout a tail

The process behind this strange phenomenon



1 Moving in closer

Hot-Neptunes like Gliese 436b probably don't start out close to their stars, but migrate inwards early in their lives. At first, their atmospheres are a mix of hydrogen and helium, with water and methane too.

2 A swollen atmosphere

Having migrated in so close to their stars that they complete orbits in just a few hours or days, hot-Neptunes begin to heat up, causing their atmospheres to expand and the water to evaporate.

3 Blown away

Hydrogen is a light gas and over billions of years is stripped away from the atmosphere, creating a tail of gas trailing in its wake. As the hydrogen is boiled away the planet is left with a helium-dominated atmosphere.

3 Cosmic jets create extragalactic electricity

Buzzing in the distant galaxy 3C303 is a huge electrical current with the same raw power as 1 trillion bolts of lightning. This immense current measures 1 million trillion amps, making it the most powerful electrical current ever found in the universe. Even scarier is how this electricity is being generated, in a jet of matter moving at almost the speed of light and blasting out from a huge black hole at the centre of 3C303 (its name means it is the 303rd object in the Third Cambridge Catalogue of Radio Sources). The black hole is consuming huge amounts of matter – gas, stars, planets and asteroids – and before it is swallowed this matter is ripped apart and finds itself in a super-hot disc of gas around the black hole. The disc is entwined with powerful magnetic fields, which are able to funnel some of the gas away into the jets. Somehow, within this maelstrom, the mighty electrical current is also being generated. Luckily, it is all happening far away from us, at a distance of two billion light years.

4 On the other side of the universe lies a world of water

In a distant galaxy 12 billion light years away is a huge volume of water vapour, totalling 140 trillion times more than all the water in Earth's oceans. The discovery of this water was made by scientists from NASA's Jet Propulsion Laboratory who used radio telescopes to identify the signature of water molecules in the light of the quasar named APM 08279+5255.

A quasar is an active galaxy powered by a supermassive black hole that is firing a jet of radiation almost directly at us. The quasar produces a thousand trillion times more energy than the Sun, and APM 08279+5255 in particular contains an estimated 4,000 times more water than the Milky Way galaxy. The water was found within a gaseous region hundreds of light years across that surrounds the galactic centre, and will possibly end up being swallowed by the black hole, giving it a drenching.

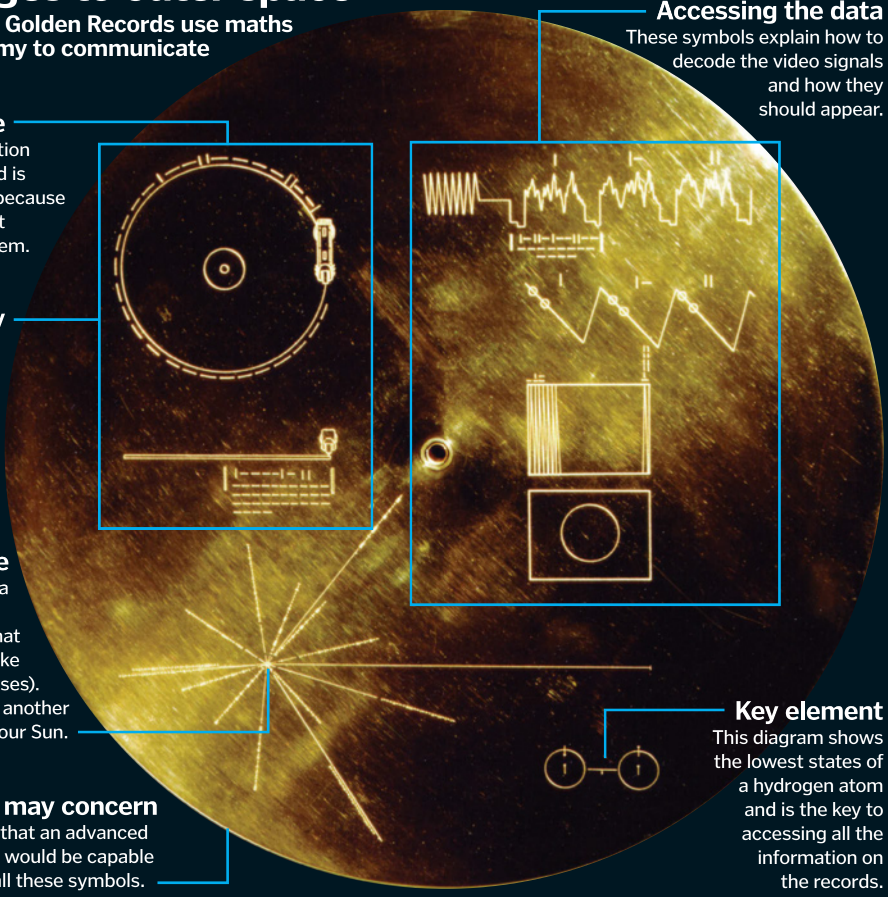
An artist's impression of a quasar hidden away inside a doughnut-shaped cloud of dust and gas that contains vast amounts of water

5 Voyager carries messages for aliens

The Voyager spacecraft – launched in 1977 and still going strong – are headed into deep space now that they have completed their tour of the planets. On the off-chance that they may be found by aliens, or even humans in the future, each Voyager spacecraft carries onboard a golden phonographic record, devised by famous astronomer Carl Sagan. The record plays natural sounds, music, images and greetings from Earth in 55 languages, while its cover contains technical information describing the world that the Voyager spacecraft have come from, and how to play the messages for any aliens who are unfamiliar with record players.

Messages to outer space

The Voyager Golden Records use maths and astronomy to communicate



Binary code
A lot of information about the record is given in binary because it is the simplest numbering system.

How to play
These are instructions on how to play the Golden Record with a stylus, included on each probe.

We are here
This diagram is a map of nearby pulsars (stars that regularly flash like cosmic lighthouses). This would help another civilisation find our Sun.

To whom it may concern
Scientists hope that an advanced alien civilisation would be capable of deciphering all these symbols.

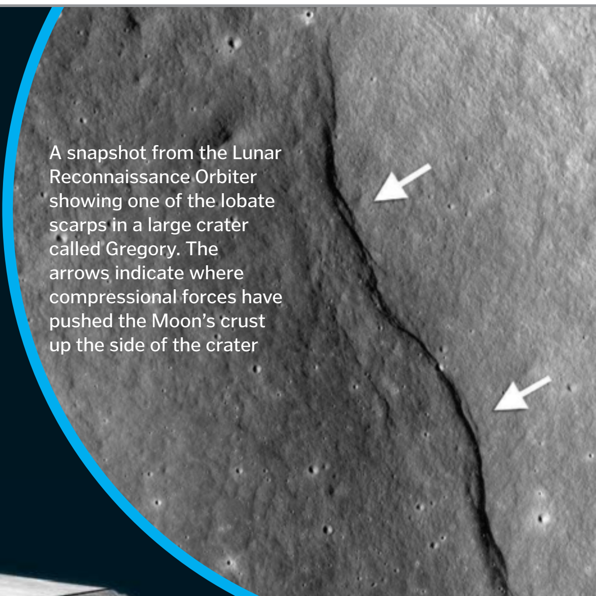
Accessing the data
These symbols explain how to decode the video signals and how they should appear.

Key element
This diagram shows the lowest states of a hydrogen atom and is the key to accessing all the information on the records.

DID YOU KNOW? *Rotating neutron stars, also known as pulsars, can spin up to 43,000 times per minute*

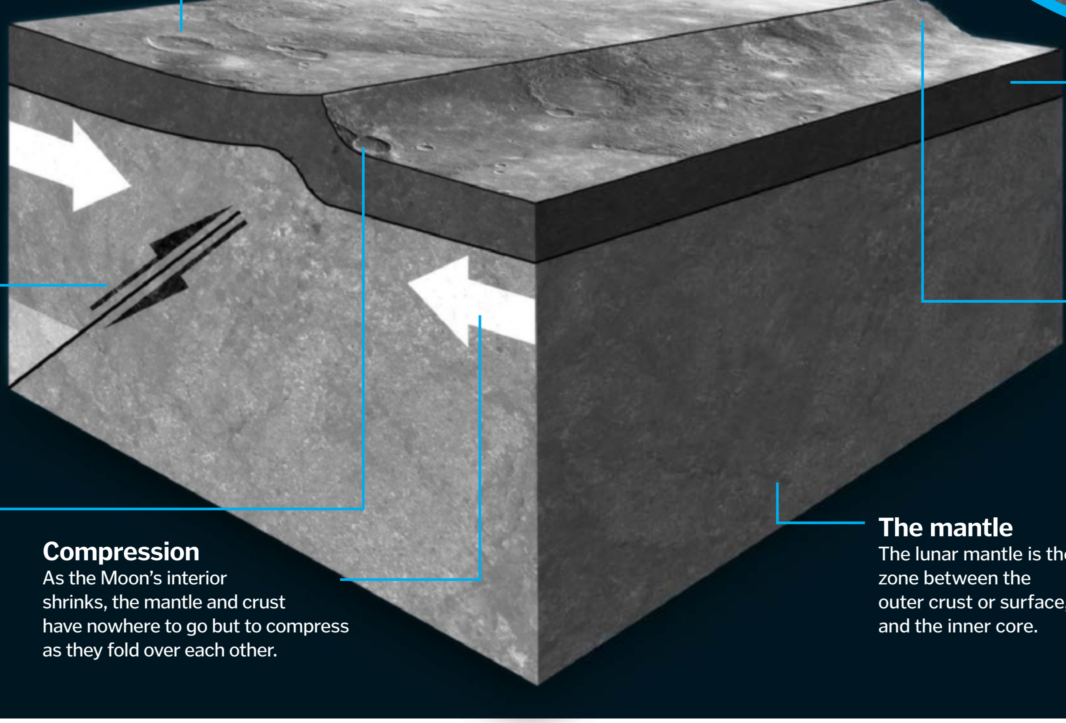
6 The Moon is shrinking!

Our Moon didn't have an easy start in life. It was likely formed in the furnace of a massive collision between Earth and a protoplanet, and has since suffered a multitude of asteroid strikes. These impacts, together with the decay of radioactive elements on the Moon, generated heat. Over millions of years our lunar companion has cooled and, as a result, shrunk. Like an apple that goes bad, its surface has wrinkled, folded and broken. NASA's Lunar Reconnaissance Orbiter has imaged giant cliffs on the lunar surface called lobate scarps, which formed when the Moon's interior contracted as it cooled and the surface, like loose skin, wrinkled. Based on the size of the biggest scarps, which formed sometime in the last billion years, the Moon's radius has shrunk by about 91 metres (300 feet).



A snapshot from the Lunar Reconnaissance Orbiter showing one of the lobate scarps in a large crater called Gregory. The arrows indicate where compressional forces have pushed the Moon's crust up the side of the crater

How the scarps form



Craters
Impacts have been steadily battering the Moon since it formed, leaving crater scars.

Uplift
The compression leads to thrust faults that lift parts of the mantle and crust over other parts.

Dating
The number of impacts on top of the lobate scarps give scientists a rough idea of how old they are.

Compression
As the Moon's interior shrinks, the mantle and crust have nowhere to go but to compress as they fold over each other.

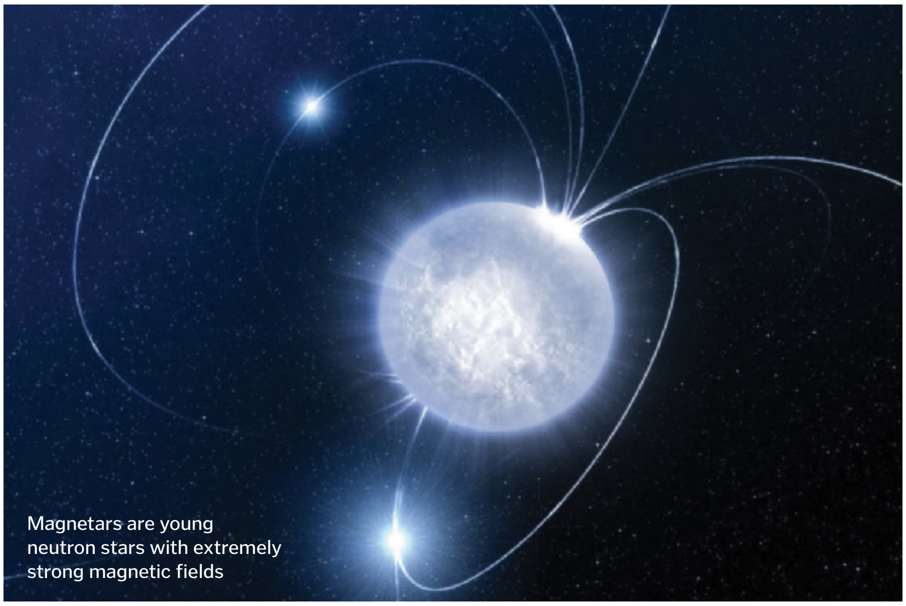
Crust
The surface layer of the Moon is called the crust, and it is about 50km (31mi) thick.

Giant cliff
The upward movement of the thrust fault breaks the crust and creates a giant cliff called a lobate scarp.

The mantle
The lunar mantle is the zone between the outer crust or surface, and the inner core.

Illustration by Tobias Roetsch

7 A teaspoon of neutron star weighs as much as humanity



Magnetars are young neutron stars with extremely strong magnetic fields

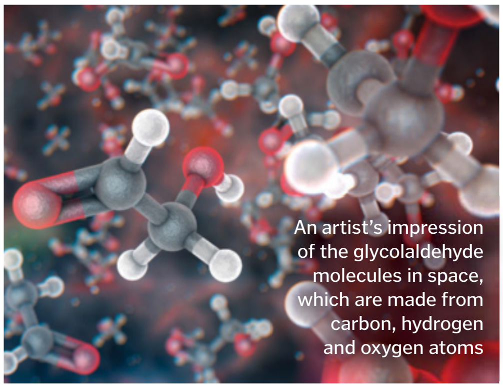
Everything about neutron stars is extreme. They pack up to twice the mass of the Sun into their tiny volumes and are incredibly magnetic. The most magnetic are called magnetars and if one were in orbit around Earth like the Moon, its magnetic field would be able to wipe every credit card on the planet. Stand on their surface and you would feel gravity 200 billion times stronger than on Earth. If the neutron star is spinning, it will fire beams of energy from its rotational axis as particles are accelerated near its magnetic poles – if we are in the line of sight of these rotating beams, we see them pulse as a pulsar.

Neutron stars are created when giant stars die in supernovas. Fusion ceases and the star collapses in on itself, compressing the core. A shock wave rebounds off the core and obliterates the star in a supernova, leaving behind the squashed core that has become so dense that it is only 11.3 kilometres (seven miles) across and electron and proton particles have been compressed together to create an object made entirely of neutron particles. A teaspoon of this would weigh ten billion tons.

8 Sugar exists in space

Sugar isn't just in your fizzy drinks and chocolate – astronomers studying the universe at radio wavelengths have also found sugar in space. Using the Atacama Large Millimeter/submillimeter Array (ALMA), which is made up of 66 radio telescopes in Chile, astronomers found sugar molecules in the form of glycolaldehyde in the gas cloud around the binary star system IRAS 16293-2422, which is still in the process of forming.

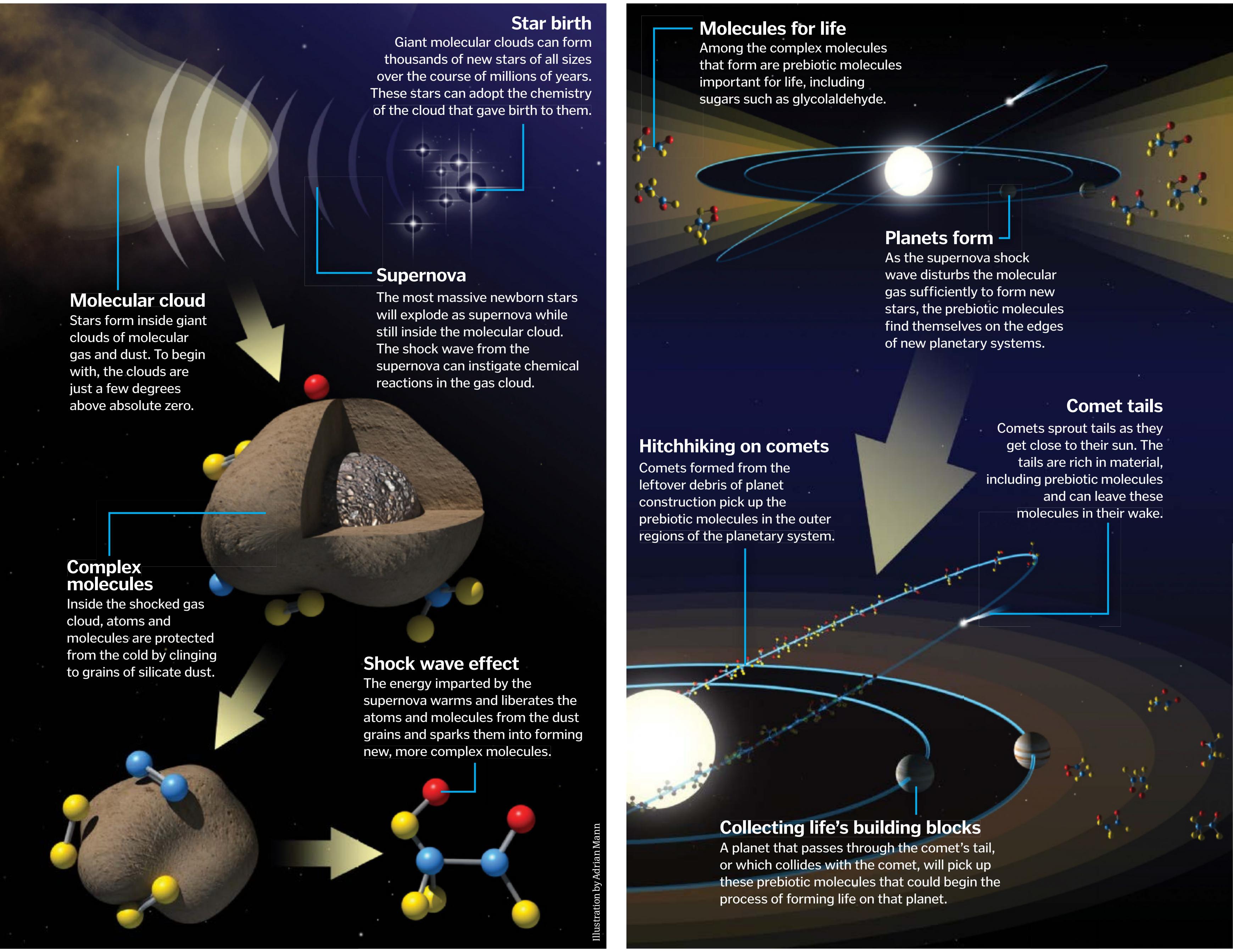
So what is sugar doing all the way out there, 400 light years away? Star-forming clouds of molecular gas are like giant natural chemistry experiments, in which all kinds of complex molecules can bond together. Sugars are fairly complex molecules and are integral to providing energy for life forms. Although there is no life in the gas cloud around the binary stars, the presence of sugar informs scientists that the ingredients for life can come from nebulae. It also implies that molecules can become quite complex in space, which means that nebulae could also be home to even more complex molecules such as amino acids and proteins, the key building blocks for life.



An artist's impression of the glycolaldehyde molecules in space, which are made from carbon, hydrogen and oxygen atoms

Making complex molecules

How are the raw ingredients for life formed in space?



Star birth
Giant molecular clouds can form thousands of new stars of all sizes over the course of millions of years. These stars can adopt the chemistry of the cloud that gave birth to them.

Molecular cloud
Stars form inside giant clouds of molecular gas and dust. To begin with, the clouds are just a few degrees above absolute zero.

Supernova
The most massive newborn stars will explode as supernova while still inside the molecular cloud. The shock wave from the supernova can instigate chemical reactions in the gas cloud.

Complex molecules
Inside the shocked gas cloud, atoms and molecules are protected from the cold by clinging to grains of silicate dust.

Shock wave effect
The energy imparted by the supernova warms and liberates the atoms and molecules from the dust grains and sparks them into forming new, more complex molecules.

Molecules for life
Among the complex molecules that form are prebiotic molecules important for life, including sugars such as glycolaldehyde.

Planets form
As the supernova shock wave disturbs the molecular gas sufficiently to form new stars, the prebiotic molecules find themselves on the edges of new planetary systems.

Comet tails
Comets sprout tails as they get close to their sun. The tails are rich in material, including prebiotic molecules and can leave these molecules in their wake.

Hitchhiking on comets
Comets formed from the leftover debris of planet construction pick up the prebiotic molecules in the outer regions of the planetary system.

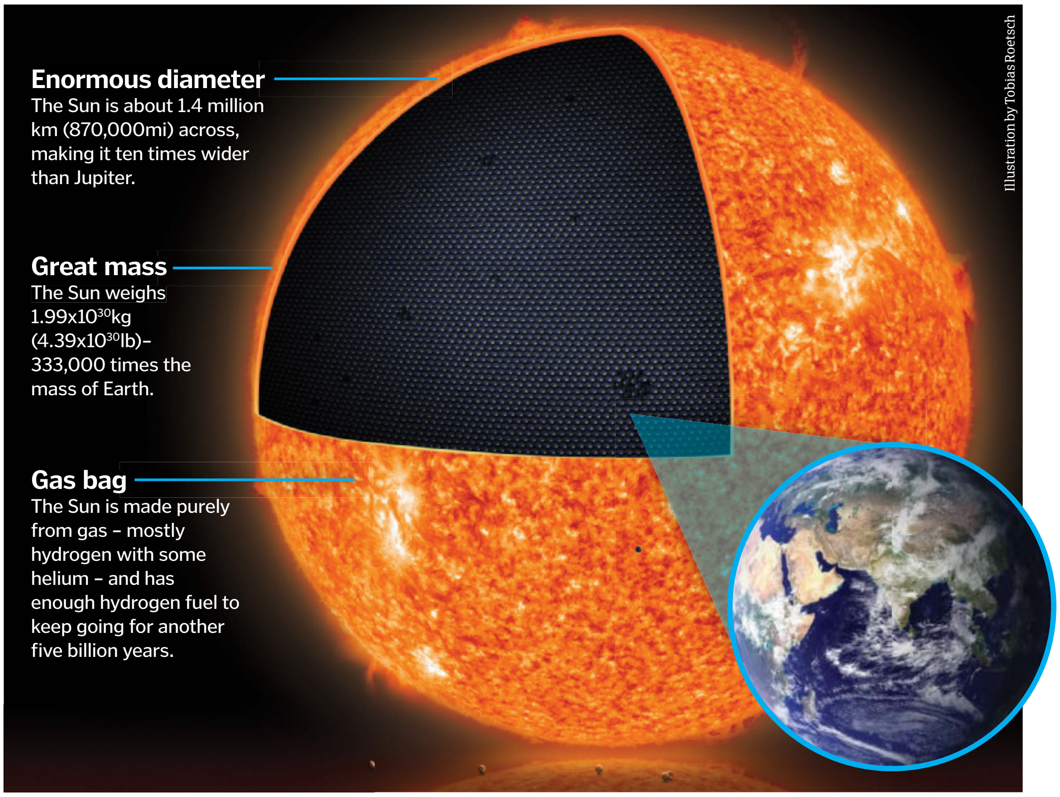
Collecting life's building blocks
A planet that passes through the comet's tail, or which collides with the comet, will pick up these prebiotic molecules that could begin the process of forming life on that planet.

Illustration by Adrian Mann

DID YOU KNOW? *Dark matter can be spotted in galaxy clusters by looking for where its gravity creates a strong lensing effect*

9 The Sun could fit 1.3 million Earths inside it

In the sky the Sun doesn't seem that big. It's half a degree across, about the same size as the Moon. However, the Moon is much closer, on average around 400,000 kilometres (249,000 miles) away, while the Sun is around 150 million kilometres (93 million miles) away, so to appear the same size as the Moon it must be huge, and it is. The Sun's diameter is 1.4 million kilometres (870,000 miles), compared to Earth's tiny 12,742 kilometres (7,918 miles) and even Jupiter's 140,000 kilometres (87,000 miles). The Sun isn't even among the biggest stars. One of the largest known stars is called UY Scuti and is 2.4 billion kilometres (1.5 billion miles) across – replace our Sun with this monster star and it would stretch almost all the way out to Saturn.



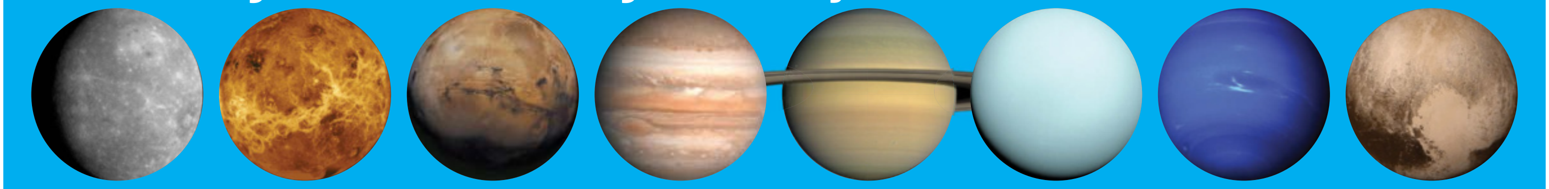
Enormous diameter
The Sun is about 1.4 million km (870,000mi) across, making it ten times wider than Jupiter.

Great mass
The Sun weighs 1.99×10^{30}kg (4.39×10^{30}lb) – 333,000 times the mass of Earth.

Gas bag
The Sun is made purely from gas – mostly hydrogen with some helium – and has enough hydrogen fuel to keep going for another five billion years.

Illustration by Tobias Roetsch

How many of each Solar System object would fit inside the Sun?

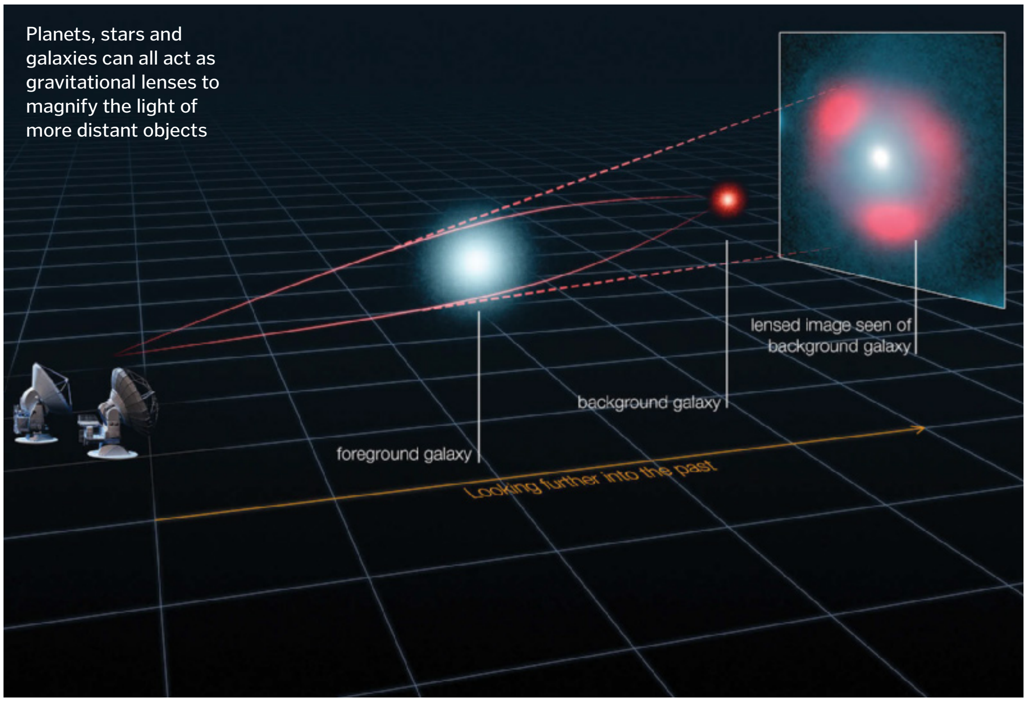


Mercury	Venus	Mars	Jupiter	Saturn	Uranus	Neptune	Pluto
23 million	1.5 million	8.6 million	1,000	1,700	20,600	22,500	200 million

10 Astronomers can use stars as telescopes

One of the key aspects of Einstein's General Theory of Relativity is that gravity can bend space, and that light passing through this region of distorted space can be magnified as though it is passing through a lens. Scientists call these gravitational lenses. Usually we see them when massive galaxy clusters filled with dark matter magnify the light of even more distant galaxies beyond, but single stars and even individual planets can also act as lenses.

Astronomers use this phenomenon to search for microlensing events, when unseen foreground planets are briefly aligned with a more distant star to magnify the star's light, letting us know the planet is there even if we can't see it. Closer to home, our Sun can be used as a gravitational lens. The focal point of this natural solar telescope is 550 times further from the Sun than Earth is, or about five times more distant than where Voyager 1 has travelled to so far. But theoretically, if we could travel to that point, we could place a space telescope that would use the Sun's gravity as an additional lens.


lensed image seen of background galaxy
background galaxy
foreground galaxy
Looking further into the past

Planets, stars and galaxies can all act as gravitational lenses to magnify the light of more distant objects

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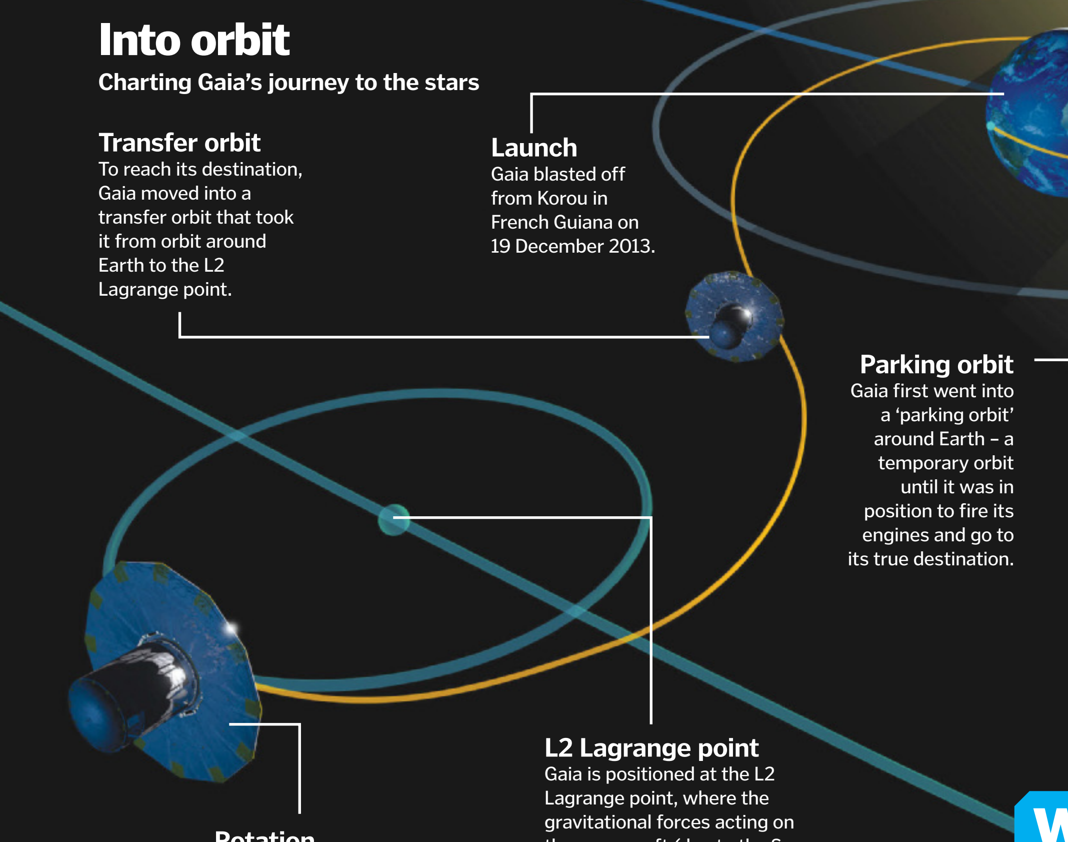
Mapping the galaxy

The Gaia spacecraft is aiming to make a three-dimensional map of the Milky Way

Into orbit

Charting Gaia's journey to the stars



Transfer orbit
To reach its destination, Gaia moved into a transfer orbit that took it from orbit around Earth to the L2 Lagrange point.

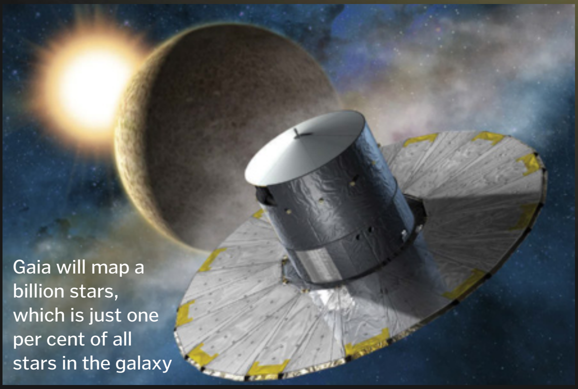
Launch
Gaia blasted off from Korou in French Guiana on 19 December 2013.

Beyond Earth orbit
Gaia has to be positioned so that the glare of the light from Earth, the Moon or the Sun does not interfere in its work.

Parking orbit
Gaia first went into a 'parking orbit' around Earth – a temporary orbit until it was in position to fire its engines and go to its true destination.

Rotation
To measure stars, Gaia slowly rotates by one degree per minute.

L2 Lagrange point
Gaia is positioned at the L2 Lagrange point, where the gravitational forces acting on the spacecraft (due to the Sun and the Earth) balance out to provide a stable orbit.



Gaia will map a billion stars, which is just one per cent of all stars in the galaxy

The European Space Agency's Gaia spacecraft is the ultimate cartographer. Its five-year goal is to make a three-dimensional map of a billion stars in our galaxy that is more accurate than anything before. Gaia, which blasted off in December 2013, is able to measure the distances and positions of stars down to an accuracy of six billionths of a degree on the sky.

Such supreme sensitivity will also give astronomers information about how the stars are moving around the galaxy and, by knowing their true distances, it will be possible to determine how bright each of these billion stars truly is. It is hoped that this data will enable scientists to build more accurate models of the evolution of stars. Gaia will also be able to discover thousands of new asteroids, exoplanets and quasars.

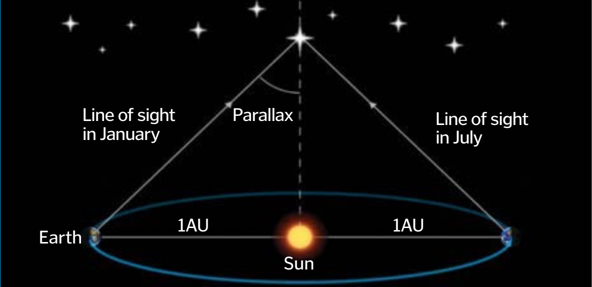
To make these measurements, Gaia is equipped with a 1.45-metre (4.8-foot) telescope and three scientific instruments. The Astrometric Instrument will measure the distances and motions of the stars, while the Photometric Instrument studies the spectra of the stars to accurately determine their luminosity. In addition, the Radial Velocity Spectrometer determines the motion of each object along Gaia's line of sight by measuring the Doppler shift in the spectrum of each object.

For optimum accuracy, there are no moving parts on board. The antenna is steered electronically rather than mechanically, and part of Gaia's chassis is a frame made from silicon-carbide, which is highly resistant to the expansion or contraction caused by changes in temperature in space. ✽

What is parallax?

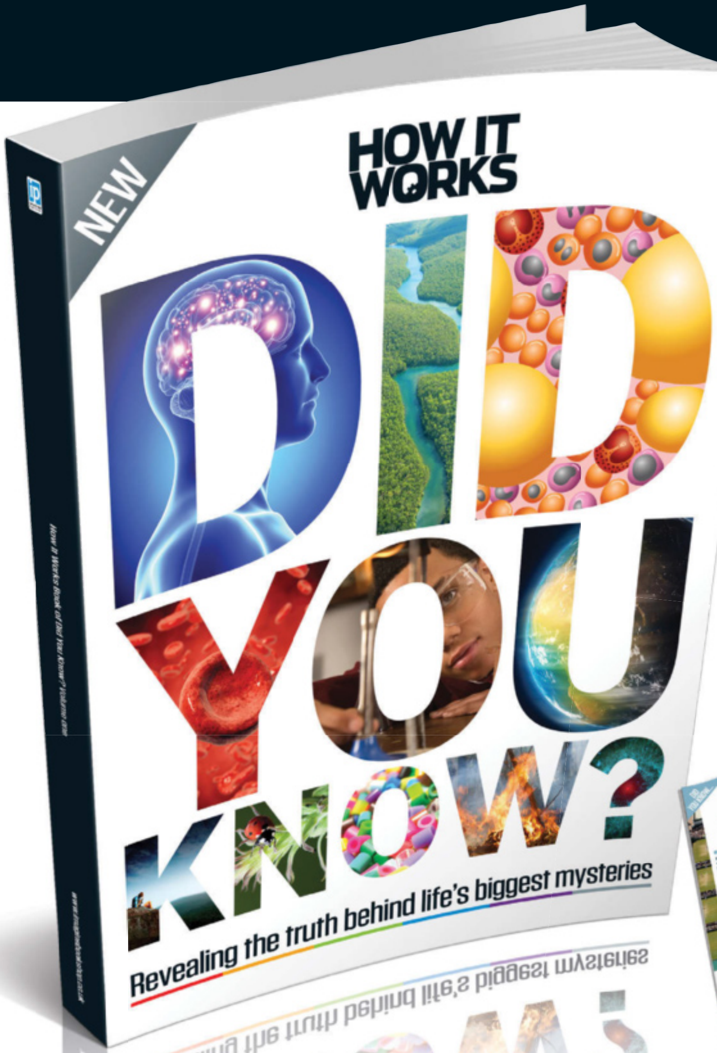
As stars are little more than pinpricks of light cast on a black background, it makes measuring their distances quite difficult. The method that Gaia is using is the parallax technique, which we use all the time. Hold up your thumb at arm's length in front of you and look at it with one eye shut. Then switch eyes – what do you notice? Your thumb appears to move with respect to the background. This is because each eye is viewing your thumb from a slightly different angle. The distance between your eyes is called the baseline and the wider the baseline, the larger the parallax angle you can measure. Gaia cannot switch eyes, but it can see the stars from different angles at opposite sides of Earth's orbit around the Sun, which has a baseline of about 300 million kilometres (186 million miles). If you know the baseline and the parallax angle, you can use trigonometry to calculate the distance.

The opposite sides of Earth's orbit create a large baseline for parallax angle measurements



1AU = 150mn km (93mn mi)

From the makers of HOW IT WORKS

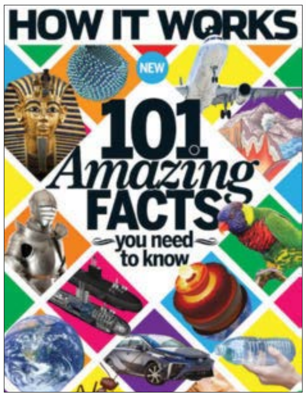


DID YOU KNOW?

Did you know that there was a Nobel Prize given for hula-hooping, or that you can print your own car? The How It Works Book of Did You Know has all the answers and more, giving you all the fact you need to wow your peers.

The Wimbledon roof spans 5,200 square meters
There are real-life zombie animals

Also available…



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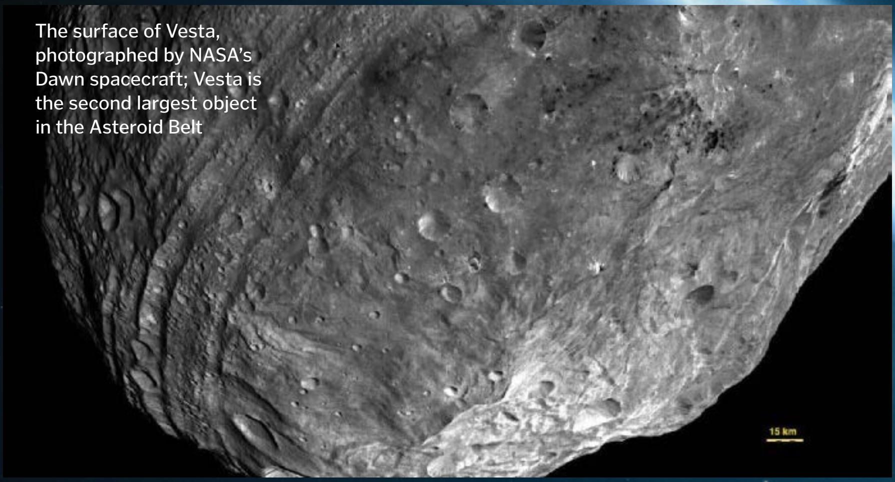
Space rocks

Your guide to planet killers, comets, meteors and more

When the planets formed 4.5 billion years ago, they grew from rocky and icy material that had condensed out of a disc of gas that surrounded the Sun. This process was messy and left the Solar System filled with rubble that comes in a range of sizes, from tiny specks of dust to half-finished proto-planets and mountains of ice that hurtle towards the Sun from the frozen depths of space. Today, we know this debris as comets, asteroids, and dwarf planets. Many of them have been relatively untouched since they formed and, by studying their chemistry and composition, scientists can learn a great deal from them about the conditions in the Solar System when the planets, including Earth, were being built.

The plane of the Solar System, known as the ecliptic, is filled with a fine haze of dust. Sometimes we can see this dust reflecting sunlight and appearing as a faint glow called the zodiacal light. Some of this dust comes from the grinding down of larger rocky bodies through collisions. These larger bodies are asteroids. Although most reside in the Asteroid Belt between the planets Mars and Jupiter, there remain many that move among the planets. The largest asteroid is Ceres and has been given the title of dwarf planet, the same label as is given to Pluto. Scientists think it is a proto-planet that was never able to fully form. When asteroids collide, they send smaller pieces spinning into space. These smaller chunks of rock are called meteoroids. Sometimes these find their way to Earth and fall through the atmosphere, and we see them as a meteor. If they don't burn up and instead reach the ground, we call them meteorites.

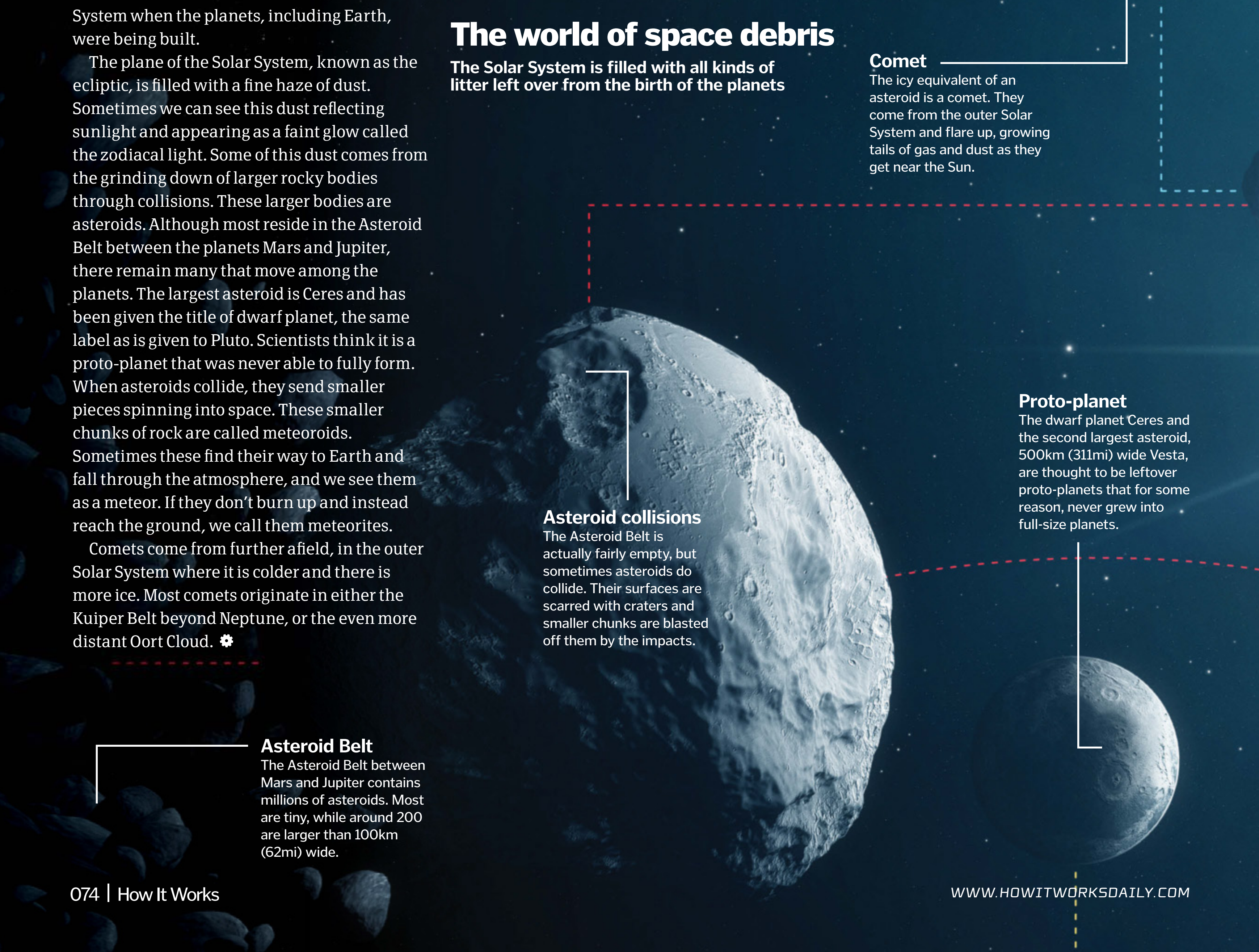
Comets come from further afield, in the outer Solar System where it is colder and there is more ice. Most comets originate in either the Kuiper Belt beyond Neptune, or the even more distant Oort Cloud. ✱



The surface of Vesta, photographed by NASA's Dawn spacecraft; Vesta is the second largest object in the Asteroid Belt

The world of space debris

The Solar System is filled with all kinds of litter left over from the birth of the planets



Comet
The icy equivalent of an asteroid is a comet. They come from the outer Solar System and flare up, growing tails of gas and dust as they get near the Sun.

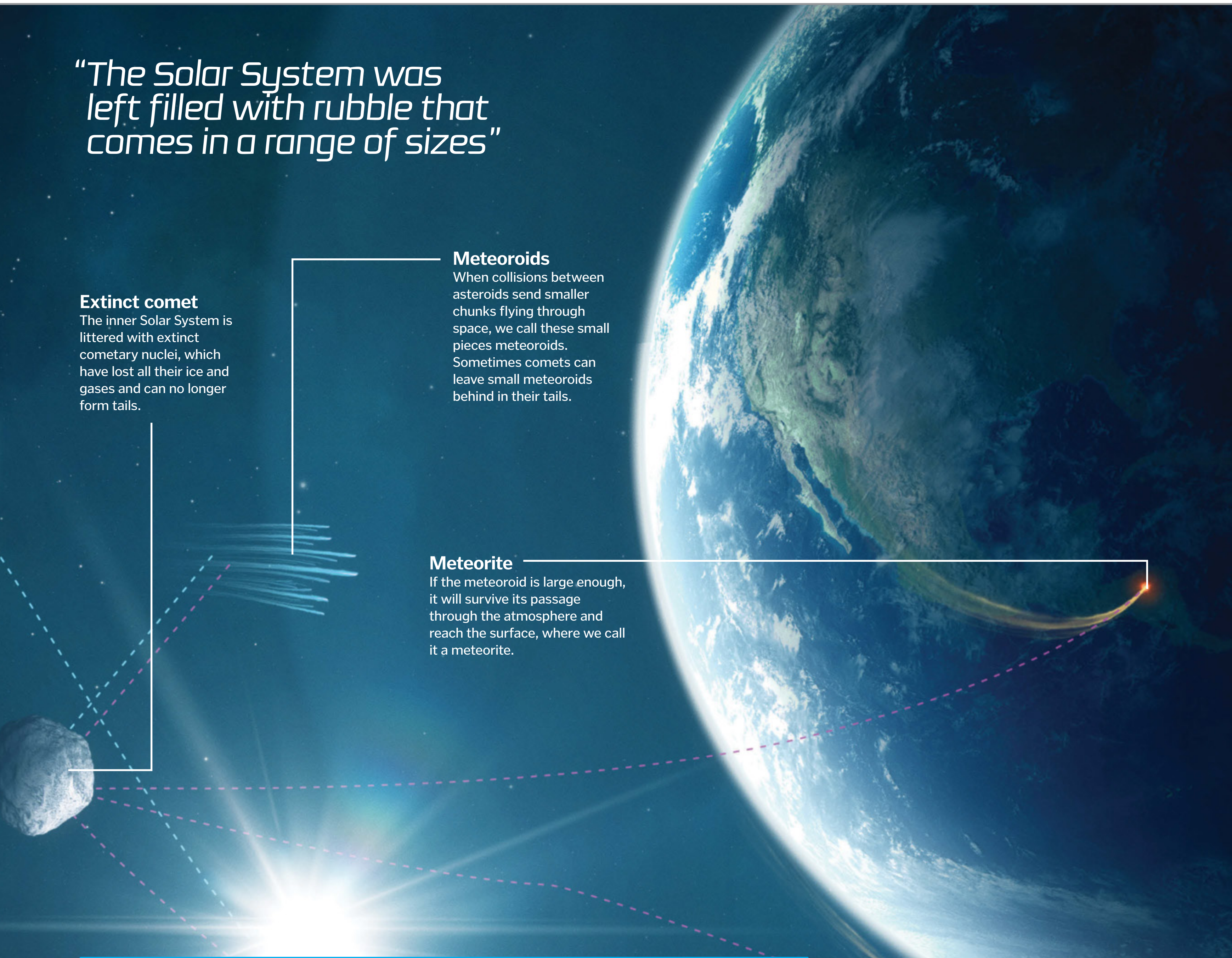
Asteroid collisions
The Asteroid Belt is actually fairly empty, but sometimes asteroids do collide. Their surfaces are scarred with craters and smaller chunks are blasted off them by the impacts.

Proto-planet
The dwarf planet Ceres and the second largest asteroid, 500km (311mi) wide Vesta, are thought to be leftover proto-planets that for some reason, never grew into full-size planets.

Asteroid Belt
The Asteroid Belt between Mars and Jupiter contains millions of asteroids. Most are tiny, while around 200 are larger than 100km (62mi) wide.

DID YOU KNOW? *There are around 4,700 potentially hazardous asteroids over 100m (328ft) wide that could one day impact Earth*

> *"The Solar System was left filled with rubble that comes in a range of sizes"*



Extinct comet
The inner Solar System is littered with extinct cometary nuclei, which have lost all their ice and gases and can no longer form tails.

Meteoroids
When collisions between asteroids send smaller chunks flying through space, we call these small pieces meteoroids. Sometimes comets can leave small meteoroids behind in their tails.

Meteorite
If the meteoroid is large enough, it will survive its passage through the atmosphere and reach the surface, where we call it a meteorite.

Meteor
When a meteoroid begins to fall into Earth's atmosphere and burn up, we see a shooting star. The technical term for this is a meteor.

Bringing space rocks to Earth

In 2016, NASA will launch one of its most ambitious missions yet, called OSIRIS-REx. Its name is an acronym for the more long-winded Origins, Spectral Interpretation, Resource Identification, Security, Regolith Explorer. The plan is to send it to an asteroid known as 101955 Bennu, where it will attempt to capture a 60-gram (2.1-ounce) sample of the asteroid using its Touch-And-Go Sample Acquisition Mechanism, or TAGSAM for short.

OSIRIS-REx will approach the asteroid until it gently touches its surface (the asteroid is too small to have enough gravity for the spacecraft to 'land'). Then it will fire jets of nitrogen gas to 'fluidise' the dirt on the surface (the technical name for this dirt is 'regolith'), allowing the capture device to scoop up a sample and store it in a capsule. When OSIRIS-REx heads back to Earth in 2023, the capsule will be ejected and will parachute back down to Earth, to be retrieved by scientists who will study the pristine sample in laboratories.

OSIRIS-REx will aim to return 60g (2.1oz) of an asteroid to Earth

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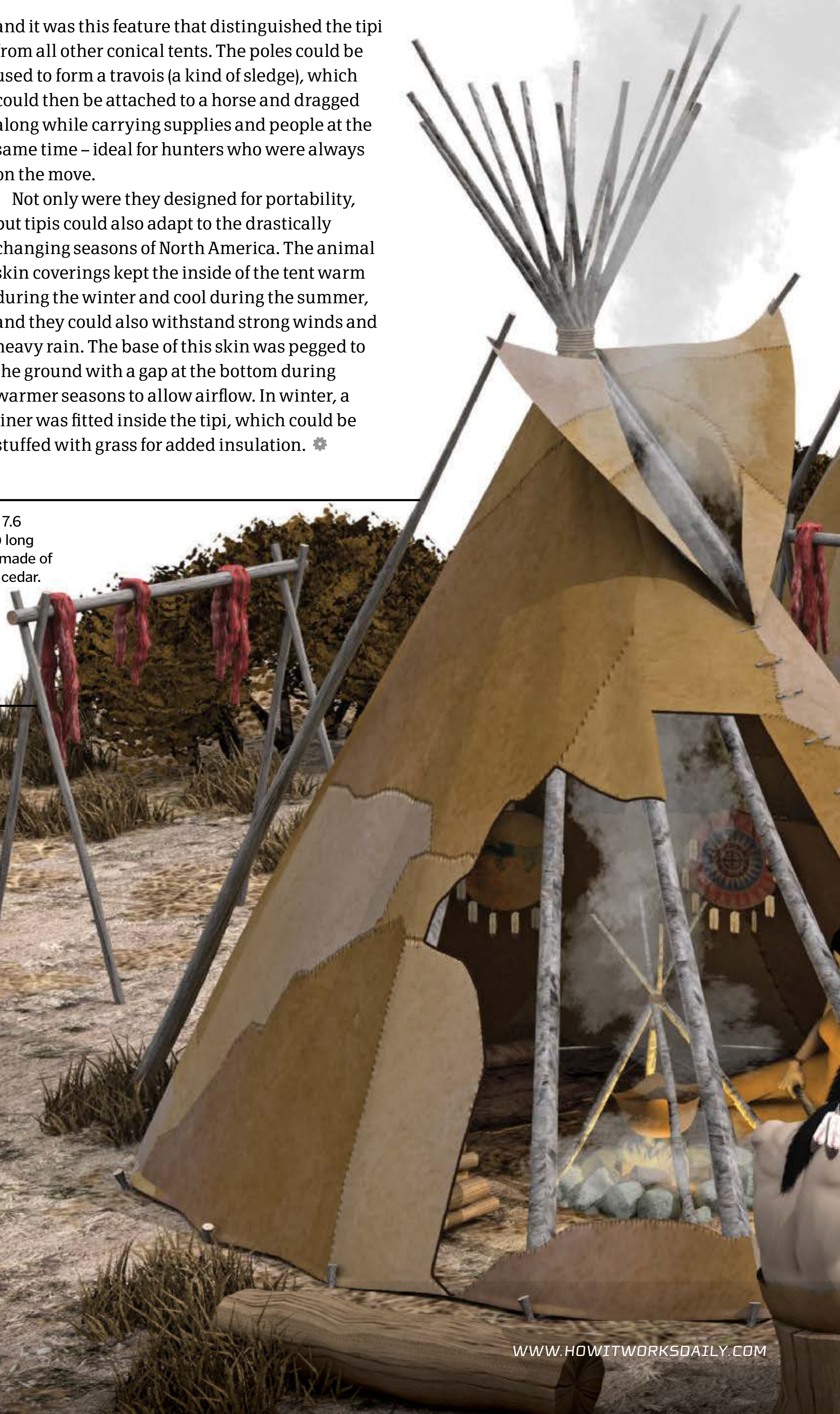
Native American tipis

Discover how these eco mobile homes were fit for wind, rain and snow

It's a common misconception that all Native Americans lived in these iconic cone-shaped tents; in fact, only the indigenous people of the Great Plains and Canadian Prairies built tipis. These tribes were reliant on wild bison for food, clothing, shelter and tools, so followed their migratory route across the North American plains, regularly moving their camps from place to place. It was therefore essential that their lodgings could be erected and dismantled quickly to suit their nomadic lifestyle.

The solution was the tipi, which is now largely out of use except for ceremonial purposes. These mobile homes were made from wooden poles with a buffalo skin covering, and had openings at the top to allow smoke from the open fire inside to escape. These flaps were positioned at right angles to the wind to prevent a downdraft, and it was this feature that distinguished the tipi from all other conical tents. The poles could be used to form a travois (a kind of sledge), which could then be attached to a horse and dragged along while carrying supplies and people at the same time – ideal for hunters who were always on the move.

Not only were they designed for portability, but tipis could also adapt to the drastically changing seasons of North America. The animal skin coverings kept the inside of the tent warm during the winter and cool during the summer, and they could also withstand strong winds and heavy rain. The base of this skin was pegged to the ground with a gap at the bottom during warmer seasons to allow airflow. In winter, a liner was fitted inside the tipi, which could be stuffed with grass for added insulation. ✲



Lodge poles
These could be 3.7 to 7.6 metres (12 to 25 feet) long and were historically made of lodgepole pine or red cedar.

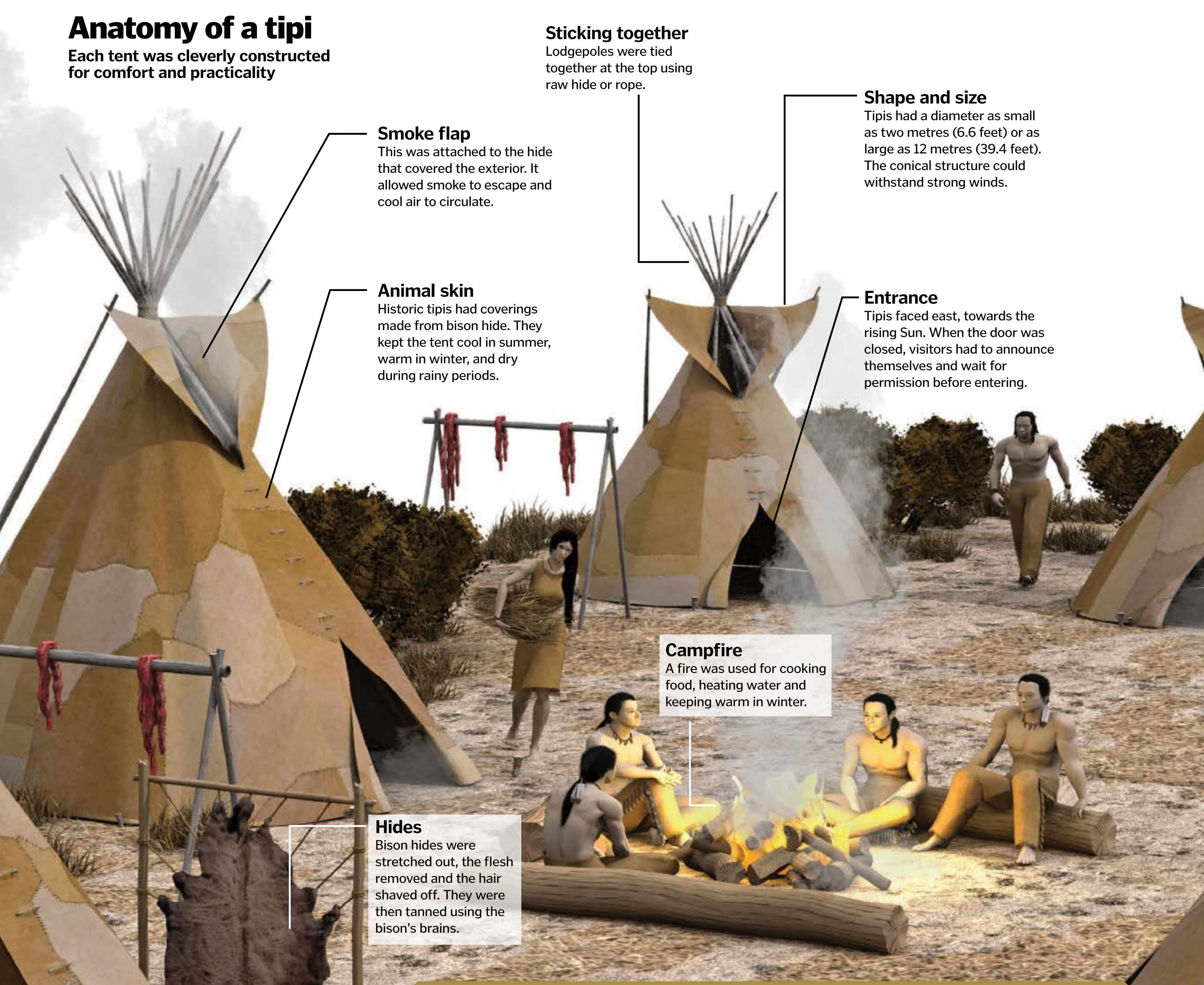
Meat
Once the bison were hunted, their meat would be cut into thin strips, hung and dried in order to preserve it.

The Oglala Lakota tribe was one of those that made tipis their home

DID YOU KNOW? *The tipi was usually constructed by female members of the tribe, and took just 30 minutes to build*

Anatomy of a tipi

Each tent was cleverly constructed for comfort and practicality



Sticking together

Lodgepoles were tied together at the top using raw hide or rope.

Shape and size

Tipis had a diameter as small as two metres (6.6 feet) or as large as 12 metres (39.4 feet). The conical structure could withstand strong winds.

Smoke flap

This was attached to the hide that covered the exterior. It allowed smoke to escape and cool air to circulate.

Animal skin

Historic tipis had coverings made from bison hide. They kept the tent cool in summer, warm in winter, and dry during rainy periods.

Entrance

Tipis faced east, towards the rising Sun. When the door was closed, visitors had to announce themselves and wait for permission before entering.

Campfire

A fire was used for cooking food, heating water and keeping warm in winter.

Hides

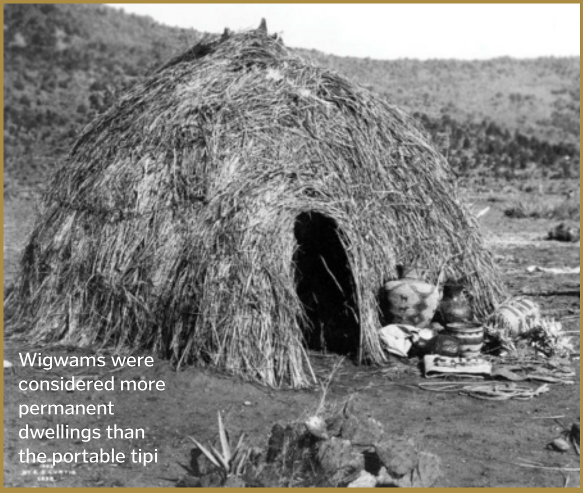
Bison hides were stretched out, the flesh removed and the hair shaved off. They were then tanned using the bison's brains.

Pets

Over time, wolves slowly developed into domesticated dogs, which were used for hunting, hauling, and kept simply as pets.

The wigwam

Often confused with tipis, wigwams (or wickiups) were dome-shaped dwellings created using a frame of arched wooden poles. Unlike tipis, these were often built as permanent homes for the Native American tribes, as they took longer to put up and were not usually portable. Their curved shape made them ideal for withstanding different weather conditions, from howling winds to torrential rain. The frame was made from young tree saplings three to 4.6 metres (ten to fifteen feet) long that were cut down while they were malleable enough to be bent into shape. Local materials were used to make the roof, ranging from grass, bark and reeds to hides or cloth. When the wigwam reached the end of its life, it was burned down and a new one erected in its place.



Wigwams were considered more permanent dwellings than the portable tipi

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The Gunpowder Plot

The plan to blow up parliament is England's most famous terrorist plot that never happened

1 Catholics are outraged

After taking the throne in 1603, King James I expels all Catholic priests from England, a Protestant state. English Catholics are furious and many begin to plot against the king.

2 The gunpowder plot begins

Guy Fawkes and 12 other Catholic gentlemen hatch a plan to blow up the Houses of Parliament in London to kill King James I and the Members of Parliament. They store 36 barrels of gunpowder in the cellar of the building, directly beneath the House of Lords.

3 A letter reveals the plot

A letter sent to Lord Mounteagle (most likely from one of the plotters, Francis Tresham, who was his brother-in-law) warns him not to attend parliament on 5 November. This letter is revealed to the king, exposing the plotters' intent to kill him.

4 The plotters are caught

Guy Fawkes is caught in the cellar with the gunpowder, then tortured and forced to confess. His co-conspirators are also tracked down, and all the plotters are hanged, drawn and quartered, or killed while trying to escape. Guy Fawkes' head is placed on display as a warning to any other traitors.

English folklore describes Robin Hood, a heroic outlaw living in Sherwood Forest

What was a medieval outlaw?

Criminals living beyond the laws of the land risked being hunted like wolves

Outlaws in medieval England were quite literally criminals who were declared to be living outside the protection of the law. If a man accused of murder, for instance, failed to attend his court proceeding and face trial, the county sheriff would be tasked with finding him. The sheriff would then make appeals at several other courts, to give the fugitive a chance to hand himself in.

However, if he still evaded capture, the court would declare him an outlaw. The Latin legal term 'caput lupinum' ('wolf's head') was used at court to label the criminal as no better than an animal to be hunted.

Only males over the age of 14 could be declared outlaws (women were declared 'waived'), and depending on the severity of their crime they could expect to lose all of their possessions, money, and any land they owned. As well as murderers; traitors, rebels or even debtors could be declared outlaws if they failed to appear at court.

Anyone could steal from, assault or even kill an outlaw and not face criminal justice themselves, as the outlaw was beyond the protection of the law. This meant that life could be incredibly harsh for an outlaw, and is why the 'writ of outlawry' was among the severest punishments of the time. ✽

DID YOU KNOW? *In the Battle of Agincourt, Henry V reportedly had so many archers that 1,000 arrows were shot each second*

How to shoot a longbow

Learn to wield one of the deadliest medieval weapons ever

A modern re-creation of an English war bow, complete with a quiver of arrows

An experienced archer could have fired ten arrows each minute

> *"Firing a longbow takes immense strength, as well as a disciplined method"*

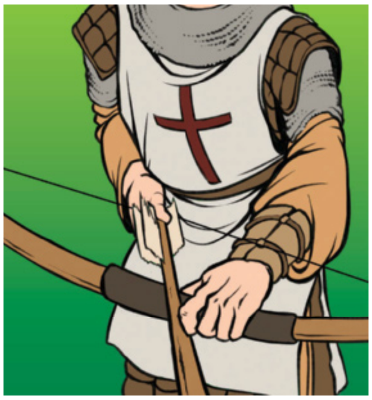
In medieval times, longbows were among the deadliest weapons you could face on the battlefield, but they are still used today for sport and even hunting. Just like in the 15th century, firing a longbow takes immense strength, as well as a disciplined method. A skilled archer would typically have been able to fire ten arrows per minute, at a range of around 230 metres (750 feet).

Mark Stretton, a Guinness World Record holder for shooting traditional longbows, has conducted experiments with these weapons and discovered that they would have been just as deadly at a distance as at point-blank range. "For the arrow to be able to make a distance of over 220 yards [200 metres (656 feet)], it must be shot at a 43-degree trajectory," he says. "[This] then means that it will reach a certain altitude before retuning to the ground. By achieving that altitude, the arrow will fall at terminal velocity, so in actual fact it cannot fall any faster no matter how high it reaches its zenith."

At the Battle of Agincourt in 1415, Henry V employed three archers for every one man-at-arms in his army. This meant the advancing French army was forced to wade through wave after wave of arrows. The English archers literally shot their king to fame at Agincourt that day, as their enemy was unable to respond to the precision and power of the longbow.

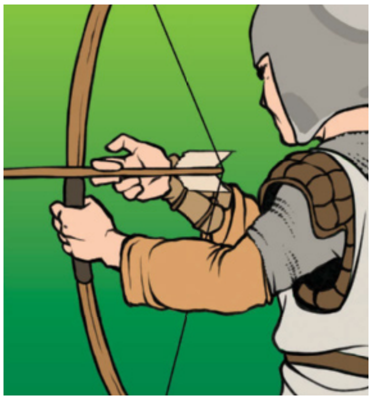
Shoot your first arrow

How to prepare and shoot an arrow from an English longbow



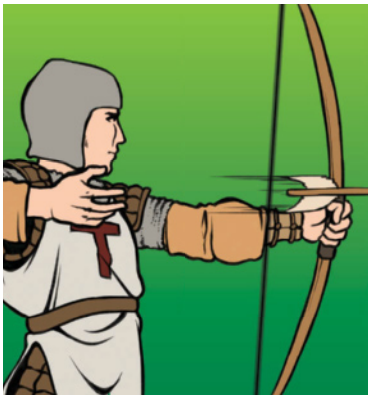
1 Assume the posture

Stand up straight, side-on to the target, with your legs positioned shoulder-width apart and your bow facing down. Position your first arrow over the forefinger of your bow hand and fix it into the bow string.



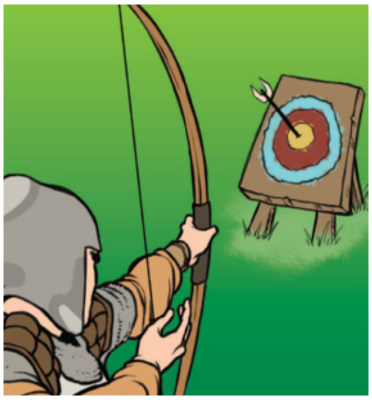
2 Draw the string

With the odd-coloured fletching of the arrow shaft, called the cock, facing away from the bow, draw the string back with your index, middle and ring fingers. Keep the front of the arrow resting on top of your bow hand.



3 Take aim and release

With the string pulled back to around your chin or cheek, steady your aim by focusing on the target, rather than the arrow. When releasing the string, continue to pull your hand back, as though stroking the bowstring as it fires.



4 Maintain position

Remain in your position until your arrow has reached its destination, which is hopefully your target! By keeping your body shape the same, you will be able to make each arrow shot as accurate as the last.

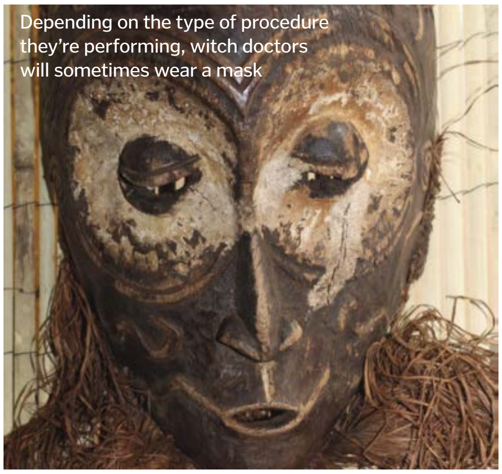
© Alamy

African witch doctors

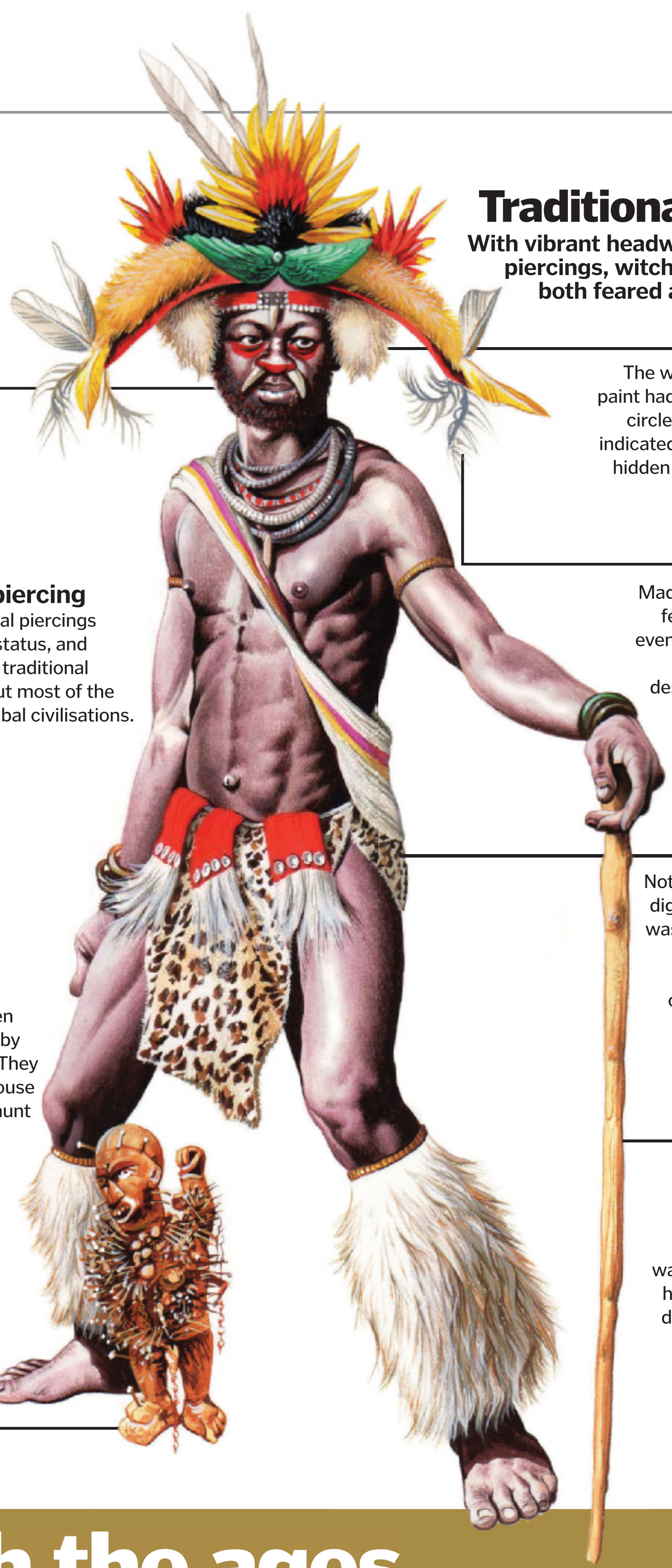
The truth behind the so-called spiritual healers

African witch doctors have been practising for around 5,000 years, and are neither witches nor doctors. Their roles and titles vary between regions and tribes but these folk healers often act as either a herbalist, a diviner, or both. They were and still are very highly respected members of society, whose aim is to cure the sick and keep evil spirits away with the help of various potions and traditions.

However, scientists hope to learn more about the effectiveness of the traditional medicines used by these healers, as they have not been well-studied. Some believe it is possible that certain herbal remedies may be beneficial in the treatment of HIV symptoms.



Depending on the type of procedure they're performing, witch doctors will sometimes wear a mask



Traditional dress

With vibrant headwear and facial piercings, witch doctors were both feared and respected

Face paint
The witch doctor's face paint had hidden meaning; circles around the eyes indicated the ability to see hidden sickness and evil.

Facial piercing
Large facial piercings signified status, and were also traditional throughout most of the world's tribal civilisations.

Headdress
Made from a range of feathers, teeth and even animal skins, the headdress was designed to impress and intimidate.

Loincloth
Not just to keep their dignity, the loincloth was a key part of the witch doctor's traditional dress, often containing a medicine pouch.

Nkondi
These small wooden statues were used by the Kongo people. They were believed to house a spirit that could hunt down enemies.

Staff
This simple tool was ideal for mixing herbal remedies or drawing in the dirt.

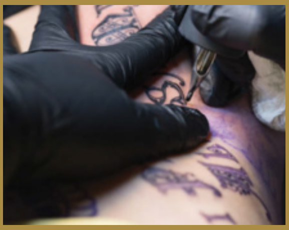
Tattooing through the ages

Find out how the use and design of tattoos has evolved

Circa 3200 BCE
Ötzi the Iceman was found preserved in the Alps in 1991, and bore the oldest examples of tattooing that have ever been discovered in Europe. He had a total of 61 carbon tattoos, mainly groups of straight lines.

Circa 800 BCE - 500 CE
Both the Greeks and the Romans used tattoos in order to identify slaves and criminals, as well as mercenaries, so that they could be found if they deserted. Tattooing may also have been used as a punishment.

1769
Captain James Cook, the famous British explorer who completed the first circumnavigation of New Zealand, discovered Polynesian tattoos after sailing into Tahiti. He also learnt the island's word for their art form: tatau.



1891
Samuel O'Reilly patented the rotary tattoo machine. It was the first tattooing device to be powered by electricity, and many of its features are still present in the modern day version, which is used globally.

Present day
Permanent body art is now socially acceptable in most parts of the world; in the United States, roughly a quarter of people aged between 18 and 50 have tattoos, and this number is on the rise.

© Getty; Thinkstock

DID YOU KNOW? *Working class Victorian families often lived in very poor conditions, with ten to twelve people sharing one room*

Inside a Victorian household

Discover how the middle classes lived in 19th century Britain

Learn more

The Geffrye Museum in London, UK, explores homes and home life through the centuries, from 1600 to the present day, reflecting changes in society, behaviour, fashion and taste. To find out more, visit **www.geffrye-museum.org.uk**.

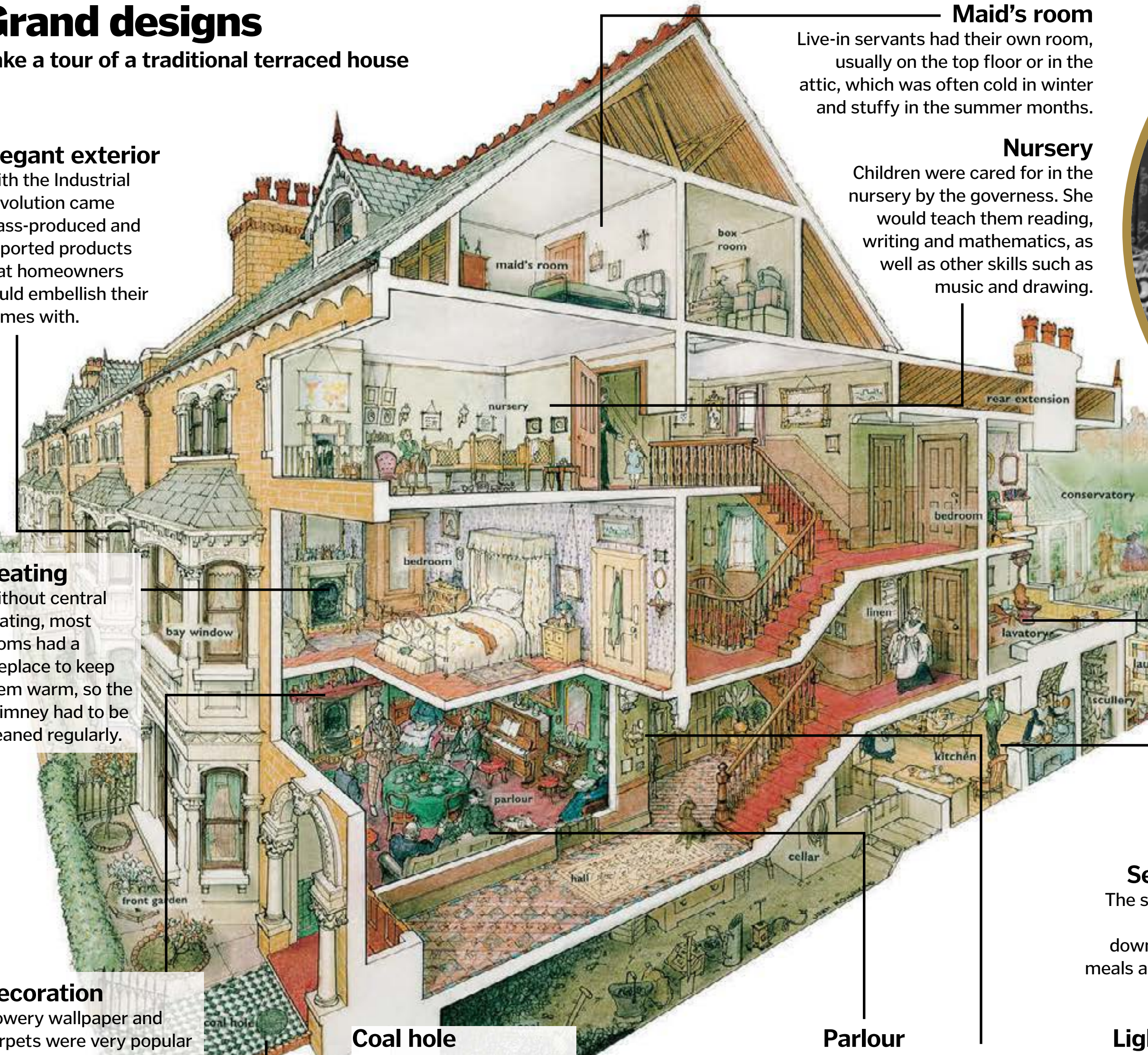
With the Industrial Revolution in full swing, many Britons benefitted from the growth of manufacturing, consumerism and overseas trade. Their increased wealth elevated them from the lowly working classes, creating a large middle class population based on self-made success rather than the inherited status of the aristocracy.

With occupations ranging from lawyers and teachers to shopkeepers and clerks, middle class men could afford to move their families to the suburbs and commute into the city for work. Their homes were typically large terraced houses, with front and back gardens and plenty of room for their wife, children and a few servants to live comfortably. The number of servants a family employed was a big indicator of their wealth, with most homes having at least one maid, one cook and a gardener. The family provided the servants with clothing, food and living quarters, and in return they would be required to work long hours for a meagre wage.

Managing the staff was often the job of the lady of the house, as middle class women rarely went out to work like their husbands. Instead, most of their time was spent entertaining guests, shopping and attending social engagements, while a governess looked after their children. The governess was employed to raise the youngsters with good manners and give them a basic education so that they would later be capable of following in the footsteps of their parents.

Grand designs

Take a tour of a traditional terraced house



Maid's room
Live-in servants had their own room, usually on the top floor or in the attic, which was often cold in winter and stuffy in the summer months.

Nursery
Children were cared for in the nursery by the governess. She would teach them reading, writing and mathematics, as well as other skills such as music and drawing.

Elegant exterior
With the Industrial Revolution came mass-produced and imported products that homeowners could embellish their homes with.

Heating
Without central heating, most rooms had a fireplace to keep them warm, so the chimney had to be cleaned regularly.

Washroom
Middle class families had the luxury of an indoor bathroom and flushing toilet. Poorer homes only had toilets outside.

Servant quarters
The servants would spend most of their time downstairs, preparing the meals and doing the laundry.

Decoration
Flowery wallpaper and carpets were very popular among the middle-classes, with ornaments and paintings providing the finishing touches.

Coal hole
Coal for the fireplaces was delivered regularly through the coal hole, sending it straight into the cellar.

Parlour
This was where guests were entertained, so the room was often decorated lavishly to indicate the family's social status.

Lighting
Candles and gas lamps would illuminate the house, as electric lights were not widely used until the end of the Victorian era.

Victorian parlours were often extravagantly decorated to show off the family's wealth to visitors

© The Geffrye Museum of the Home / design John Ronayne; Corbis

BRAIN DUMP

Because enquiring minds need to know...

Want answers?

Send your questions to...

How It Works magazine @HowItWorksmag

howitworks@imagine-publishing.co.uk

MEET THE EXPERTS

Who's answering your questions this month?

Luis Villazon

Luis has a degree in zoology from Oxford and another in real-time computing. He builds steampunk gizmos and electronic gadgets, and his articles about science, tech and nature have been published around the world.

Laura Mears

Laura studied biomedical science at King's College London and has a master's from Cambridge. She escaped the lab to pursue a career in science communication and also develops educational video games.

Alexandra Cheung

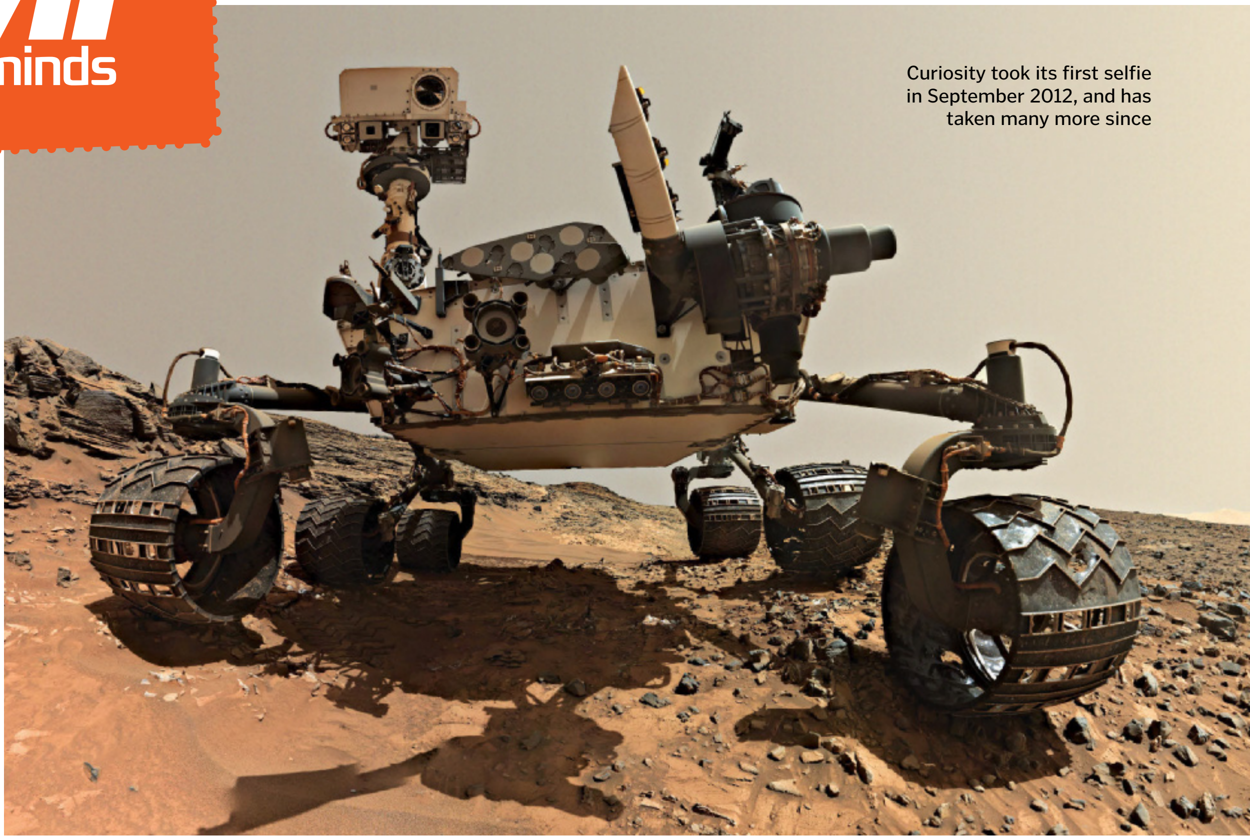
Having earned degrees from the University of Nottingham and Imperial College London, Alex has worked at many prestigious institutions, including CERN, London's Science Museum and the Institute of Physics.

Sarah Bankes

Sarah has a degree in English and has been a writer and editor for more than a decade. Fascinated by the world in which we live, she enjoys writing about anything from science and technology to history and nature.

Shanna Freeman

Shanna describes herself as somebody who knows a little bit about a lot of different things. That's what comes of writing about everything from space travel to how cheese is made. She finds her job comes in very handy for quizzes!



Curiosity took its first selfie in September 2012, and has taken many more since

How does the Curiosity rover take selfies without its arm showing?

Martha Flash

Mars rover Curiosity creates its stunning selfies by stitching together over 50 individual images, with the overlap in this patchwork of images allowing it to edit out its robotic arm. Just like a human, Curiosity captures its selfies by holding its camera, the Mars Hand Lens Imager, at arm's length. It then rotates its robotic arm, taking shots from many different angles in a well-rehearsed sequence. The length of its arm makes it easy to keep it out of most of the shots. If Curiosity's arm does appear in any of these initial snapshots, the overlap between the images means that it can be cut out of the final image. **AC**

How did pilots navigate in the dark before GPS?

Bernadette Collins

It was extremely difficult. The street lighting of towns and along major roads would have provided some clues but during World War II, with blackouts over Europe, night bombers flew with a navigator who used the airspeed and compass bearing to plot a course on a map. Over water, some planes were fitted with a calibrated periscope sight that allowed them to measure their motion relative to wave crests and so compensate for a crosswind. Later 'LORAN' and 'Decca' radio stations were set up around the coast and planes could compare the timing of signals from different stations to triangulate their position. **LV**

Even at night, the view out of the pilot's window is still important for navigation

Why don't we sweat in hot water?

Terri Eldridge

■ We do sweat in hot water – in fact, we sweat constantly, although you probably don't notice it. If you've ever got into a bath or shower that's too hot, you may have found your head or other parts not submerged feel sweaty. But even the parts of your body underwater are also sweating. Since the water washes the sweat away, it's unable to evaporate from your skin and cool you off. In other words, the sweat is unable to do its job. Spending too much time in hot water – such as in a hot tub or warm springs – can cause you to overheat. **SF**

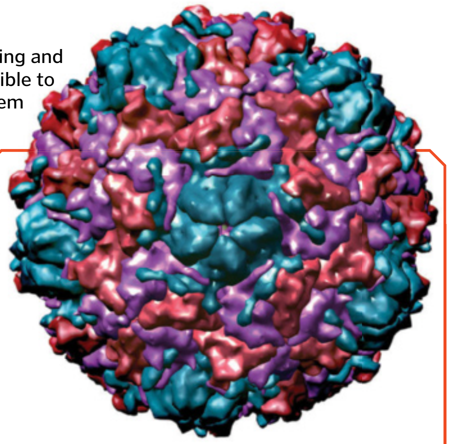
Hot water can actually make you sweat quite a bit!

It's possible, although unlikely, to get sunburnt through a car window

Can you get sunburnt through glass?

Millie Rodgers

■ The glass used for windows typically filters out 97 per cent of the UVB rays, which can cause sunburn and skin cancer, so it is unlikely that you would get burnt unless you were in the Sun for a long time. However, glass is far less effective at blocking UVA radiation, eliminating just 37 per cent. UVA light causes skin to age more rapidly and may also contribute to some types of skin cancer, so it's still wise to apply sunscreen. Car windscreens typically contain a layer of plastic that filters out all UVB radiation and 80 per cent of UVA. **AC**



Rhinoviruses are constantly changing and adapting, making it almost impossible to develop effective drugs to fight them

Why can't we cure the common cold?

Anna Trent

■ The common cold is caused by a number of different viruses, making it hard to tackle the infection with a vaccination or cure. Over half of the cases of common colds are thought to be caused by rhinoviruses, but there are more than 100 unique variants of these, and they are constantly adapting and evolving. Attempting to create a cure would be entering a biological arms race that we would be extremely unlikely to win – by the time we came up with a good drug, the cold-causing viruses would have mutated. Preventing the common cold from spreading is far easier than trying to eliminate it altogether. **LM**

FASCINATING FACTS

How deep can a human dive unaided?

According to the worldwide freediving organisation AIDA International, the world record for diving without the help of air tanks, fins, or ropes is 101 metres (331 feet), set by William Trubridge of New Zealand in 2010. **LM**

Without air tanks, freedivers must learn to hold their breath for a long time

There's no real evidence that breathing in sea air is good for you

Why is sea air good for you?

Harry Duncan

■ Sea air has long been thought to be a cure for many ills. Victorians visited seaside resorts to take in the supposedly restorative air, but it may just have been a respite from the sooty cities. Whether sea air actually is good for you is a matter of debate. Some believe that the moist air full of salt, iodine, and other minerals stimulates the immune system and can clear the lungs of those with respiratory illnesses. There's some anecdotal evidence that patients with cystic fibrosis can breathe better after spending time at the ocean, but there's no statistical evidence to support it yet. In some cases at least, healthy people report feeling better because they're relaxing, feeling lulled by the sound of the waves, and getting more exercise. **SF**

BRAIN DUMP

Birds get static shocks from wires, but they don't get in a flap about it

Why are birds not electrocuted when they land on electricity wires?

Betty Gomez

■ Birds normally only sit on a single wire, so they act like a resistor in parallel with the wire. Electricity can either flow through the wire, or up one leg, through the bird and down the other leg. As the bird is a much worse conductor than the wire, almost all of the electrical current flows through the wire. However, birds do experience a brief static shock when they land on a wire, because their body acts like a capacitor that gets charged up. But a bird is a very weak capacitor and the shock amounts to less than half a milliamp. **LV**

The sky's weight comes from the entire volume of air stretching into the upper atmosphere

How much does the sky weigh?

Amelia Gardner

■ A rough estimate of the entire weight of the atmosphere, as experienced at the Earth's surface, would be a whopping 5 million billion tons. The 'sky' is made up of all the molecules in the atmosphere, which press down on you from above and in all directions to create what is known as air pressure. On average, this column of air weighs 1.05 kilograms per square centimetre (15 pounds per square inch). Multiply this by the Earth's total surface area (510 million square kilometres or 197 million square miles) and you can deduce the total mass of our planet's atmosphere. **AC**

Despite their name, grapefruits are not related to grapes

Are grapefruits actually related to grapes?

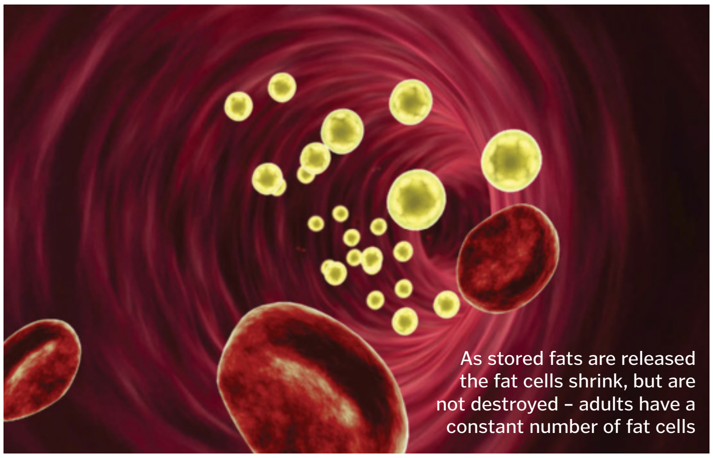
Kara Fielding

■ Only distantly – the citrus grapefruit is only related to the grape in the sense that they are both fruits. Although early records suggest the grapefruit was given its name because its taste resembles that of the grape, the two flavours are actually very different, so this theory seems unlikely. A popular belief is that grapefruits were named after the way they grow on trees, in clusters that resemble bunches of grapes. An alternative theory relates to the grapefruit's ancestor, which is called a pomelo. The pomelo's Latin name is Citrus maxima, which roughly translates to 'great fruit' – a relatively easy jump to the word grapefruit. **SB**

When you lose weight, where does the fat go?

Graham Sanders

■ Fat reserves are essentially a store of energy; they help to safeguard the body against times of famine. When people use more energy than they take in, stored fat can be burnt as additional fuel. When energy stores in the body are low, the stored fats in adipocytes (fat cells) are broken down into glycerol and fatty acids, and these are subjected to a series of chemical reactions to convert the stored energy into a useable form. The fatty acids and glycerol are released into the blood so they can travel to the liver, where can these molecules can either be broken down even further or used them to make glucose for energy. **LM**



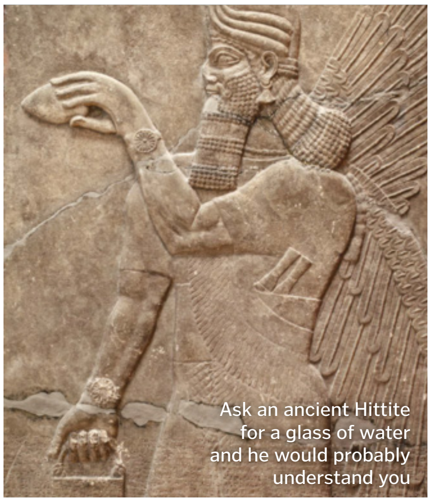
As stored fats are released the fat cells shrink, but are not destroyed – adults have a constant number of fat cells

What are the oldest words in English?

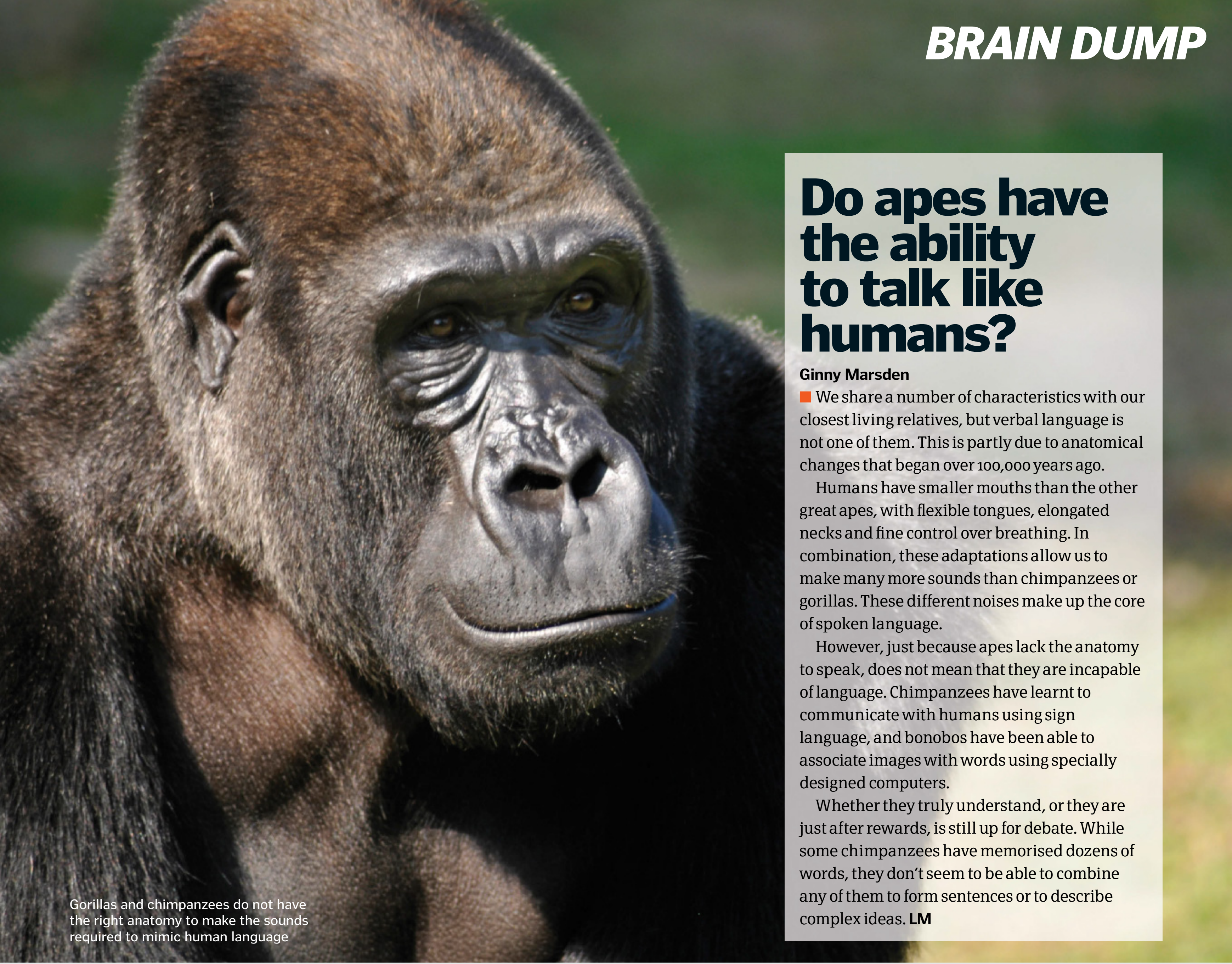
Fred Potter

■ English has many words that are borrowed from the Romans (agenda, complex, libido) and the ancient Greeks before them (agnostic, crisis, rhinoceros) but these were only added to the English language in the middle ages, as scholars began incorporating words from their Latin and Greek education.

The very oldest words are for the most basic ideas. The word 'water' for example is essentially the same as the ancient Hittite word 'watar' or 'wadar' and probably dates back to the Indo-European tribes from 4000 BCE. But researchers at the University of Reading in 2009 compared the sounds of words across all the seven basic families of human language and found that only one word had a root that was common to all of them. That word was 'thou' which is the singular form of 'you'. The words I, we, give, man, mother, fire, bark and worm were some of the close runners-up. **LV**



Ask an ancient Hittite for a glass of water and he would probably understand you



Do apes have the ability to talk like humans?

Ginny Marsden

We share a number of characteristics with our closest living relatives, but verbal language is not one of them. This is partly due to anatomical changes that began over 100,000 years ago.

Humans have smaller mouths than the other great apes, with flexible tongues, elongated necks and fine control over breathing. In combination, these adaptations allow us to make many more sounds than chimpanzees or gorillas. These different noises make up the core of spoken language.

However, just because apes lack the anatomy to speak, does not mean that they are incapable of language. Chimpanzees have learnt to communicate with humans using sign language, and bonobos have been able to associate images with words using specially designed computers.

Whether they truly understand, or they are just after rewards, is still up for debate. While some chimpanzees have memorised dozens of words, they don't seem to be able to combine any of them to form sentences or to describe complex ideas. **LM**

Gorillas and chimpanzees do not have the right anatomy to make the sounds required to mimic human language

Gagging when someone vomits seems to be an evolutionary trait

Why do I gag when someone is sick?

Celia Gibson

This phenomenon is also known as sympathy vomiting. Scans of the brain have actually shown that when you see someone vomiting, your brain has the same activity as if you're the one vomiting. You're feeling the same disgust that they are. Scientists think that this could be the source of empathy, and may also be an evolutionary tool. If someone in your family clan ate food that had gone bad, it's likely that you would have eaten it too. If it caused them to vomit, it would be better for you – from an evolutionary standpoint – to also vomit and get rid of any toxins. Unfortunately, this seems to be hard-wired into our brains. **SF**

FASCINATING FACTS

How does Wi-Fi work on transport when it's not connected to anything?

Trains and coaches have onboard routers that connect to mobile phone networks. Many passenger planes are now fitted with satellite routers to provide internet access even over the ocean. **LV**

In-flight Wi-Fi is expensive because it relies on satellite links

Why does banana skin get thinner as it ripens?

Trent Davey

An unripe banana skin is full of water, which makes it thick enough to protect the fruit inside from insects in the wild. The outer layer of banana skin is fairly watertight, though, so the banana stays relatively dry. However, as the banana ripens, it absorbs water from the skin via the process of osmosis. The skin cells consequently wilt and lose their rigidity, making the overall skin much thinner. This makes it easier for animals and birds to tear them open and transport the seeds, while feeding on the fruit at the same time. **SB**

BRAIN DUMP

FASCINATING FACTS

What is in belly button fluff?

Belly button fluff forms when body hair on the lower abdomen act like tiny hooks, picking up clothes fibres, hair and dead skin cells, and depositing them in the navel. **AC**

Men tend to collect more belly button fluff since they have more body hair

Why is a marathon 26.2 miles?

At the 1908 London Olympic Games, the marathon distance was extended to 26.2 miles, so participants would run from Windsor Castle to White City stadium, finishing in front of the Royal Family's viewing box. **SB**

A marathon was adjusted to 26.2 miles in 1908 to please the British Royal Family

Are women really better at multitasking than men?

It seems to depend on the situation. Men may be better at juggling a variety of tasks than women, but women seem to prioritise them better and are more likely to complete all of their tasks. **SF**

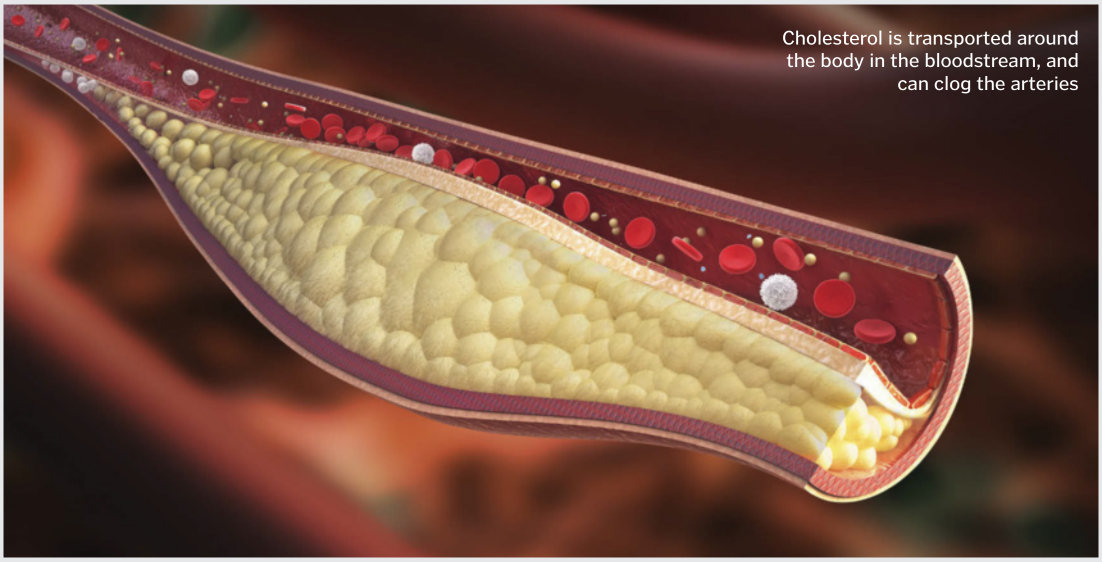
Women are better at multitasking – in some instances, anyway

Fish and cetaceans evolved their swimming apparatus separately

Why do fish have vertical tails and whales have horizontal ones?

Ben Lowry

■ There is, as you might have guessed, an evolutionary explanation for this. Fish evolved from the earliest vertebrates, which undulated along the seabed. Their muscles therefore move the spine from side to side, and a vertical tail is perfect for this sort of slithering movement. On the other hand, whales and other cetaceans (such as dolphins) evolved from land mammals that walked on four limbs and therefore had flexible spines. Their muscles evolved to enable an up-down motion and are positioned above and below the spine. A whale's fluke (the two lobes of its tail) is moved by these muscles, and so also moves up and down. **SB**


Cholesterol is transported around the body in the bloodstream, and can clog the arteries

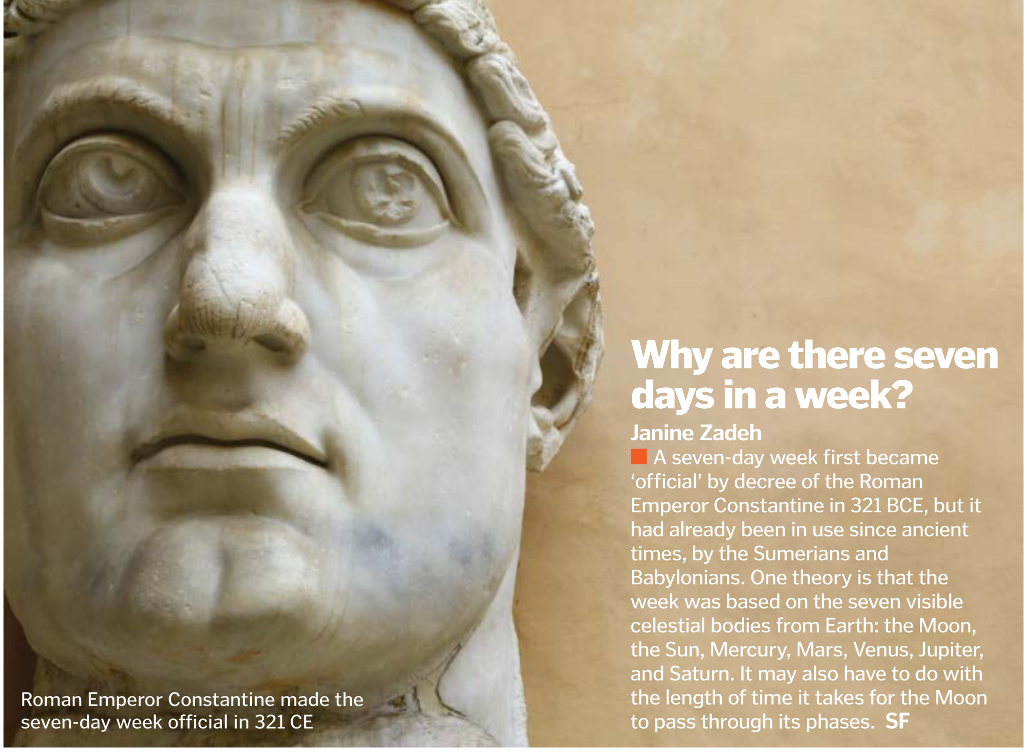
What's the difference between good and bad cholesterol?

Mike Weightman

■ Cholesterol doesn't dissolve well in water, so it is packaged up into structures called lipoproteins for transport in the bloodstream. There are different types of lipoproteins, and these are commonly described in the media as 'good' and 'bad' cholesterol.

Low density and very low density lipoproteins (LDL and VLDL) are responsible for carrying cholesterol to tissues around the body. They are known as 'bad' cholesterol because they can drop their cargo inside blood vessels, causing them to clog.

High density lipoproteins (HDL) take cholesterol from the body to the liver. They are able to remove some of the deposits left in the arteries, and are known as 'good' cholesterol. **LM**



Roman Emperor Constantine made the seven-day week official in 321 CE

Why are there seven days in a week?

Janine Zadeh

■ A seven-day week first became 'official' by decree of the Roman Emperor Constantine in 321 BCE, but it had already been in use since ancient times, by the Sumerians and Babylonians. One theory is that the week was based on the seven visible celestial bodies from Earth: the Moon, the Sun, Mercury, Mars, Venus, Jupiter, and Saturn. It may also have to do with the length of time it takes for the Moon to pass through its phases. **SF**

In the UK, plumbers are advised to place the hot tap on the left

Why is the left tap always for hot water and the right for cold water?

Ed Lawrence

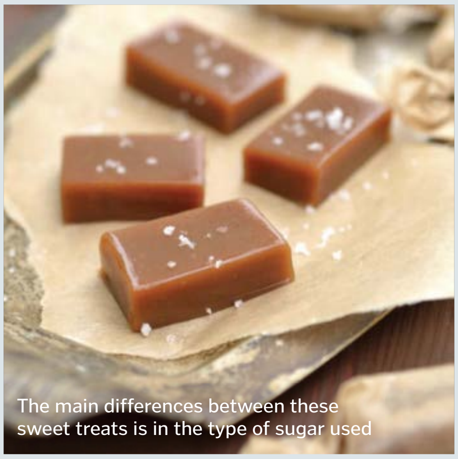
■ Water was originally hand-pumped into the sink and the handle was on the right of the tap, since most people are right handed. Later, when hot water was piped into homes, that tap had to go on the left. This convention is now written into British Standard 'BS EN 200' that regulates sanitary tapware. This is because, whatever the original reasons were, it is better for everyone to use the same layout to prevent scalds when someone accidentally turns on the wrong tap. But this isn't generally enforced and many houses actually have DIY plumbing where the taps are reversed. **LV**

How do we make our voices quieter when we whisper?

Larry Yung

■ When you whisper, you speak without allowing your vocal cords to vibrate, which means that you produce a quieter sound. Your vocal cords (also called vocal folds) are a pair of membranes that sit across your larynx. In normal speech, you hold your vocal cords closed across your airway and expel the air from your lungs, causing the membranes to vibrate and produce sound as the air escapes in bursts. In order to whisper, you first hold the vocal folds slightly apart so that they no longer touch. As air passes through the resulting gap, it creates turbulence as the air moves in many directions. This creates much softer vibrations in the larynx, resulting in a quieter sound. Unlike in normal speech, this turbulent flow of air contains many frequencies of sound, resulting in a husky effect. You can feel the difference in the vibration of your vocal cords if you touch your throat while speaking and then compare it to whispering. **AC**

Whispering allows you to speak at a lower intensity by reducing the vibrations of your vocal cords



The main differences between these sweet treats is in the type of sugar used

What's the difference between caramel, toffee and butterscotch?

Hannah Buckhaven

■ The main difference between caramel and butterscotch is in the type of sugar used. Caramel is made with melted white, granulated sugar, whereas butterscotch is made with melted brown sugar.

Both caramel and butterscotch sauces are also made with cream, butter and vanilla. However, the sugar and cream are more prominent in caramel, whereas the sugar and butter are more prominent in butterscotch. Both also benefit from a pinch of salt, but you're more likely to notice its absence in butterscotch than you are caramel. The suffix 'scotch' refers to the method of cutting, in that butterscotch candy is 'scotched' or scored to make it easier to cut or break later.

Toffee, on the other hand, is quite simply butterscotch that has been cooked for longer, and at a higher temperature, until it has reached what is known as the 'hard crack' stage. This means that it has a 99 per cent sugar concentration. **SB**

New Brain Dump is here!

■ Don't miss issue 30 of **Brain Dump**, the digital sister magazine to **How It Works**, when it lands on the virtual newsstand on 5 November. You'll find out why your voice sounds different on a recording, whether we could ever visit a multiverse and how electric freezers get so c-c-cold! Also in this issue: opera singers, VTOL drones and spiders who have had too much caffeine. Every edition is packed with stunning images and fun facts to entertain your friends and family with. Download the new issue of **Brain Dump** at the beginning of every month from iTunes or Google Play. If you have a burning question, you can ask at **www.facebook.com/BraindumpMag** or Twitter – the handle is **@BrainDumpMag**.

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THE WISH LIST

The tech behind the latest must-have gadgets

Car gadgets

Enhance the driving experience with the ingenious kit that can keep you safe and entertained on the road

1 Make coffee on the go

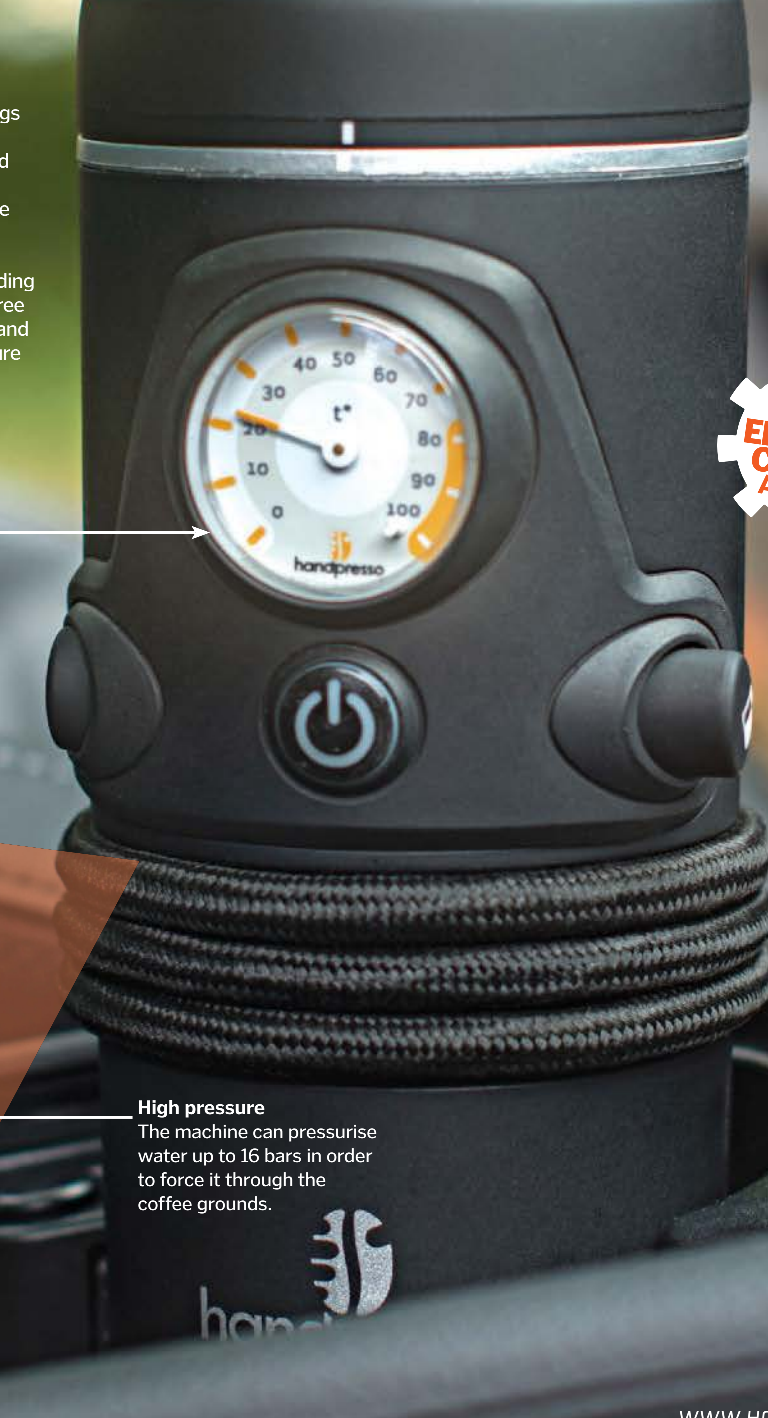
Handpresso Auto

£139 / $199

www.handpresso.com

If you're craving a hit of caffeine on a long car journey and there's no motorway service station in sight, then the Handpresso can come to your rescue. This little machine plugs into the cigarette lighter in your car to brew the perfect espresso in just two minutes. You will need to come prepared with the main ingredients though, so make sure your car is stocked up with bottles of water and some compatible coffee pods, or a pot of your favourite ground coffee. The machine works by boiling the water and then forcing it through the coffee grounds at high pressure. You can stop it early depending on your temperature and taste preference, or wait for the three beeps to tell you when it's finished. Then simply turn it over and pour your fresh espresso into the cup provided. Just make sure your car is stationary before you start brewing!

The perfect shot
The Handpresso fits into your car's cup holder and can produce 50ml (1.7fl oz) of espresso at a time.



Heating up
This handy gauge lets you see when your coffee reaches the perfect temperature.

HOW IT WORKS EDITOR'S CHOICE AWARD

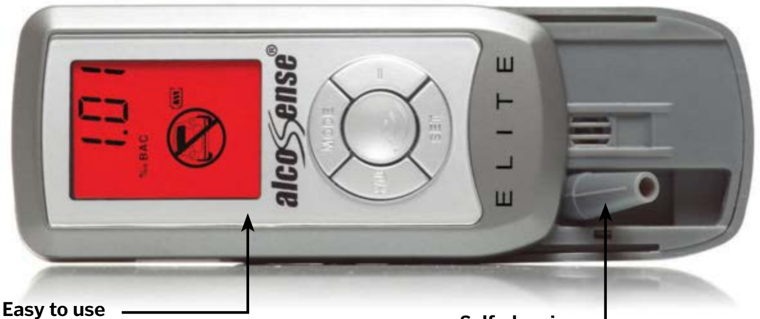
High pressure
The machine can pressurise water up to 16 bars in order to force it through the coffee grounds.

2 Make hands-free calls

Parrot MiniKit Neo 2 HD
£69.99 / $99.99
www.parrot.com
Want to be able to make hands-free calls without having to wear a headset? The Parrot MiniKit Neo 2 simply clips on to your car's sun visor, connects to your phone via Bluetooth and uses its built-in speaker and microphone to enable you to make and take calls. It also features voice recognition to detect your commands, so you can control several of your phone's features, including streaming music and sending automatic SMS replies, while driving. The device can even help you find your parked car by memorising its own GPS position when Bluetooth is disconnected.

3 Check you're safe to drive

AlcoSense Elite
£59.99 (approx $90)
www.alcosense.co.uk
Knowing whether you are over the drink-drive limit can be difficult if you've had a couple of drinks or it's the morning after. By blowing into the AlcoSense Elite personal breathalyser you can confirm whether you are safe to drive in a matter of minutes. It works by measuring the concentration of alcohol vapour in your breath to accurately judge the amount of alcohol in your blood stream. It can be set for different country's drink drive limits, clearly showing you if you are too drunk to drive by changing the screen from orange to red.



Easy to use
An airflow sensor alerts you if you have blown too hard or too softly and need to do another test.

Self-cleaning
The Elite automatically cleans its sensor after every use to ensure the reading is accurate.

4 Track your stolen car

SPOT Trace
£84 / $119.95
www.findmespot.com
Your car is likely to be one of your most expensive possessions, and unfortunately that makes it very attractive to thieves. For peace of mind, the SPOT Trace can help you make sure your vehicle is safe and sound, or track it if it does get taken for a joyride. Once you attach the GPS tracker to your car, you can see its coordinates by logging in to the website or smartphone app. Thanks to the in-built vibration sensor it can also detect if your car is moving and instantly send you an email or text message to let you know.

EXTRAS

The gear that will give you added driving know-how

BOOK

How It Works Book Of Amazing Vehicles

£9.99 (approx $16)
imagineshop.co.uk
From the first Ford to the fastest fighter jets, discover some of the finest inventions in the world of transport. There's also an in-depth look at iconic vehicles throughout history and a sneak peak at how we'll get around in the future.

APP

Waze

Free
iTunes/Google Play
This community-based navigation app lets you share real-time traffic information with millions of other users, so everyone can find the best route. You can even share updates about local petrol prices so users can be sure that they're always getting a good deal.

WEBSITE

ViaMichelin.com

This route planning website will give you detailed directions for any journey in the UK or Europe, and even calculate how much it will cost in fuel when you input a few details about your car.

5 Record collisions

Garmin Dash Cam 35
£159.99 / $199.99
www.garmin.com
By constantly recording the view through your windscreen, the Dash Cam 35 ensures you have a reliable eyewitness account of any driving incidents. Automatic Incident Detection means the camera knows which recordings to save, and stamps them with the correct time, location, speed and direction of travel. The wide-angle lens captures high definition video of the entire road in both bright and low light conditions, or can be removed from the windscreen to take snapshots of any vehicle damage. The Dash Cam will even warn you if you are driving too close to the car ahead and alert you to speed cameras and red lights.

6 Get WiFi in your car

EE Buzzard 2
£19.99 (approx $30) plus monthly fees
www.ee.co.uk
Keep your passengers entertained on long, boring car journeys with your very own WiFi hotspot. The Buzzard 2 dongle plugs into your car's power socket to convert 4G mobile internet into WiFi. It can support up to ten devices, so everyone can stream the movies or music they want, and also serves as a USB charger for when battery levels get low. The device costs £19.99 when purchased with a 30-day contract, but if you sign up for a year then you get it completely free. Then you can get one gigabyte of data for £10 a month, or three gigabytes for £15 a month.

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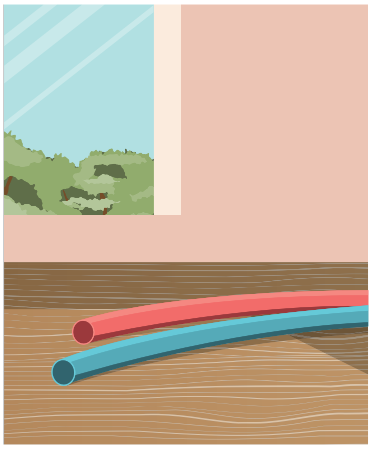
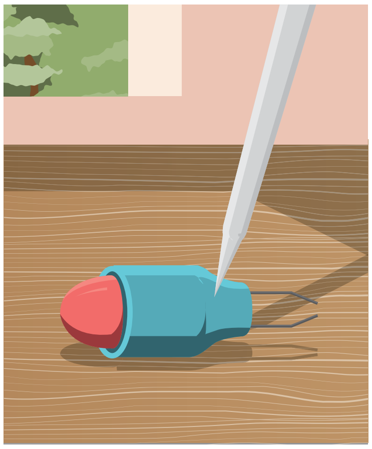
Build your own robot

With a bit of know-how, you can make your own moving, light-up android



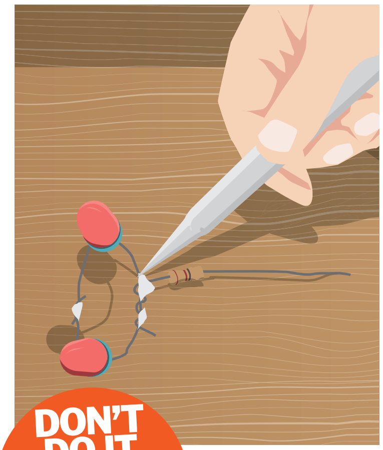
1 Pick your heat shrink

To protect the delicate LED lights that will form the robot's eyes – as well as add some attractive colour – you'll need to get your hands on some heat shrink tubing. This durable and heat-resistant material is normally used to insulate wires and is available to buy from hardware stores. You will only need around ten centimetres (four inches), so check if you have any lying around the house first.



2 Prepare your LEDs

Cut two small pieces of heat shrink roughly 1.25 centimetres (0.5 inches) long. To be extra precise, measure the length of your LED pins so you know how much shrink tubing is needed to cover the majority of the pins (but leave the ends exposed). Slide the LEDs into the heat shrink until the light-up tips peek out, and then secure it by carefully holding a hot soldering iron close to it.

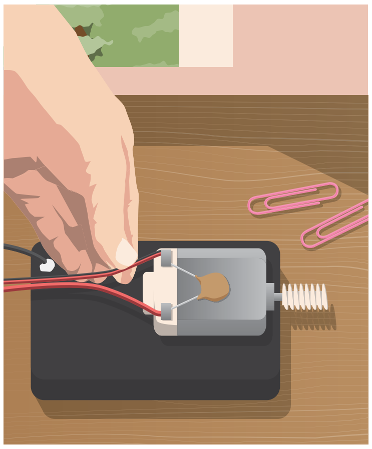


3 Solder your battery pack

To connect the LEDs and resistor to the battery pack you'll need the soldering iron again. Take some insulated wire and use it to connect the battery pack to the resistor, which in turn connects to the LEDs. Start by soldering the two LEDs' positive and negative ends to one another, and then solder one end of the resistor to an LED's positive end and the other to the battery's positive end.

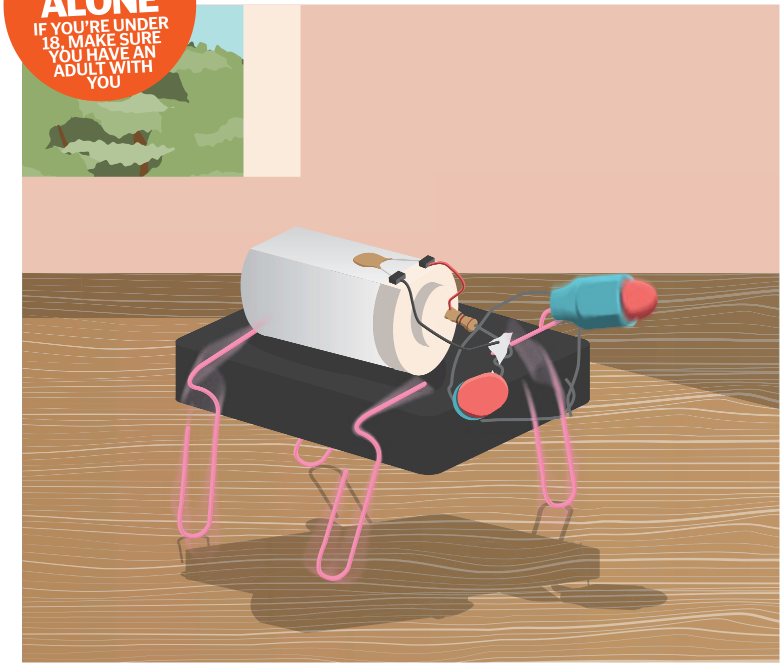
DON'T DO IT ALONE

IF YOU'RE UNDER 18, MAKE SURE YOU HAVE AN ADULT WITH YOU



4 Attach the legs and the motor

Finish off by soldering the negative (black) wire of the battery to one of the LED's short terminals. For the robot's legs, bend four paper clips and glue one to each corner of the battery pack, so that they prop up the main body evenly. You then need to solder the vibrating motor's wires to the battery pack; make sure you remember to wire up both the positive and negative ends correctly!



5 Finish your robot

Use hot glue to secure the motor to the top of the battery holder, making sure that the wires can't interfere with the robot's legs. Finally, attach the battery holder's wires to the small motor pins that sit on top of the motor, and then insert the batteries. If everything is wired up correctly, your homemade robot will light up and start moving! Make sure you keep it on a flat surface that it can't fall from.

In summary...

The robot you've created moves in a slightly unconventional way, using vibrations created by the motor. The paperclips need to be precisely positioned so that the robot is able to move; if they aren't aligned and don't evenly support the robot's body, the chances are it will either move erratically or topple over.

Disclaimer: Neither Imagine Publishing nor its employees can accept liability for any adverse effects experienced after carrying out these projects. Always take care when handling potentially hazardous equipment or when working with electronics, and follow the manufacturer's instructions.

NEXT ISSUE

- Build your own torch
- Construct a periscope

Make invisible ink

Learn how to write secret messages that can be revealed by the power of heat

Illustrations by Edward Crooks

1 Prepare your lemon juice

Take a lemon and cut it in half, with the supervision of an adult if necessary. Squeeze half the lemon, using a lemon squeezer or by hand. Pour the lemon juice into a separate bowl and add a few drops of water. This dilutes the lemon juice, making it near impossible for anyone to see with the naked eye once your message has been written on paper. This is because lemon juice contains carbon compounds that are colourless at room temperature.

2 Write your message

Take a writing implement and dip it into your lemon juice mixture. We recommend that you use a cotton bud, but other options such as a brush, a dry fountain pen or even a feather will work too. Take a plain piece of white paper and carefully write out your message, remembering to dip your writing utensil regularly to ensure it has plenty of lemon juice on it. When you are finished, leave the paper to dry in a safe place.

3 Reveal your secret writing

You can tell when the paper has dried because the message will be completely invisible. Pick the paper up and slowly heat it, near a hot light bulb or with a hairdryer. Slowly but surely, your secret message will appear! This experiment works because the heat breaks down the compounds in the lemon juice, releasing carbon. When the carbon comes into contact with the air, it starts a process called oxidation, which turns it brown.

In summary…

The diluted lemon juice is colourless at room temperature, allowing your message to stay secret until heat is applied. As you warm up the paper, the carbon compounds in the lemon juice release their carbon, which reacts with oxygen to turn those parts of the paper brown, revealing the message.

Virtual weapons
Throw your opponent off course by firing digital weapons, such as plasma cannons.

Smart tracking
R.E.V vehicles can track each other from up to 5m (16.4ft) away, helping you avoid, or initiate, collisions.

WIN!

Robot racing cars

Robotic Enhanced Vehicles (R.E.V) from WowWee come in pairs and are built for racing. You control one via an app on your smart device, while the other is controlled by your friend or an artificially intelligent virtual driver.

Which of the following is James Bond's car in the new Spectre movie?

a) **Lotus Esprit** b) **Aston Martin DB10**
c) **Mini Cooper**

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INBOX

Speak your mind…

Get in touch

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WIN!

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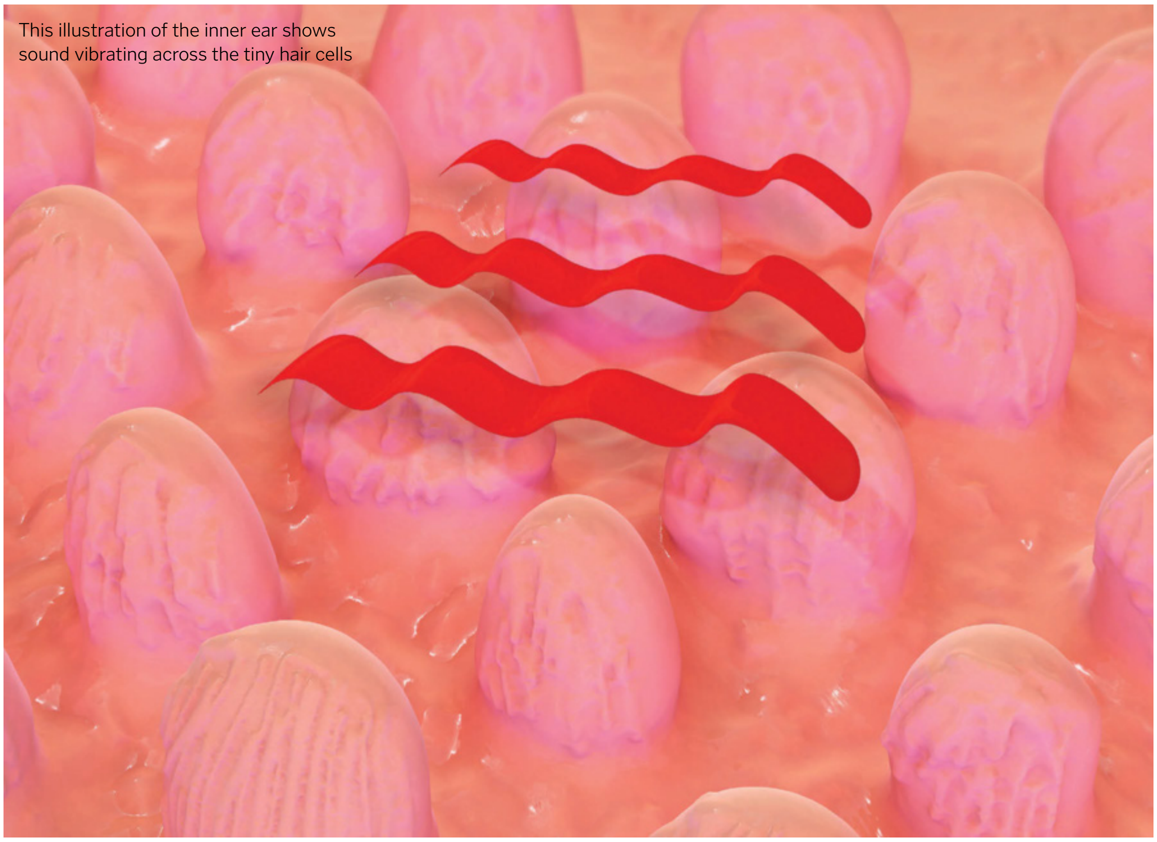
Part of a series of brilliantly informative books, *Stargazing* gives an overview of our Solar System, and helps you to see it for yourself.

Letter of the Month

Why do our ears ring?

Dear **HIW**,
My question for you is why do our ears ring when we hear a loud noise? I hope you find time to answer!
Yours sincerely,
Jack Mallin

We've found the time, Jack! Inside our inner ears are tiny cells called hair cells. When any sound hits them, they convert the vibrations into electrical currents that can then be sent to our brain via auditory nerve impulses. On top of the hair cells are the stereocilia, which move when they deflect sound waves through the ear. The louder the sound, the more the stereocilia move. Exceptionally loud noises damage these hair-like extensions and cause them to keep sending an electrochemical signal to the brain, which is what causes your ears to ring. If the ringing has started after a rock concert, it's likely that the ends of the stereocilia have actually broken off, and you've developed a temporary form of tinnitus. Fortunately the tips of the stereocilia are able to grow back in around 24 hours, so the ringing is usually only temporary.



This illustration of the inner ear shows sound vibrating across the tiny hair cells

Does wheel size affect fuel economy?

Dear **HIW**,
I drive a Toyota Yaris hybrid with 16-inch wheels. Why is it that the same car with 15-inch wheels gives better fuel economy when they both have the same engine? How does this work?
Thanks,
Glenn Thompson

Excellent question, Glenn. Fuel economy is a very complex subject, which car manufacturers spend a lot of time researching. How fuel-efficient your car is depends on a number of factors, not just the wheel size or the engine size. Your 16-inch wheels may actually be more efficient than the 15s in certain situations. Generally, driving a car with smaller wheels around town is more efficient, because they need less force to start turning. However, if you're cruising along the motorway, you're better off with larger wheels, as they require less energy to keep them spinning.

Having alloy wheels can boost your fuel economy, as they are lighter than the traditional steel wheels

The science of wind turbines

Dear **HIW**,
I love reading your magazine each month; it always gets me thinking! I spend a lot of my time in Cornwall and I can't help but notice that there are so many wind turbines. How do they work?
Thanks,
William Tucker (aged 14)

In essence, wind turbines work in the opposite way fans do, in order to create electricity from wind. Natural winds turn the turbine's blades, which spin a shaft connected to a generator that makes electricity. The onboard computer is attached to a weather vane that makes sure the turbine's blades are angled to take advantage of the wind direction, allowing the maximum amount of energy to be generated.

By 2050 it is hoped that wind power will generate a staggering 50 per cent of Europe's electricity demand

© NASA; Thinkstock

It may be possible to tell apes apart by their fingerprints, just like humans

Animal fingerprints

■ Dear **HIW**,

I am currently living in Iraq, and love your magazine so much that I get my brother to send it to me every month! I've read that apes have fingerprints just like we do; can they be used to identify different individuals like they can in humans?

Thanks,

Noor Alossmi (aged 9)

Greetings to all our Iraqi readers! Many of our closest relatives, including gorillas and chimpanzees, produce fingerprints similar to our own. Amazingly, koala bears also produce fingerprints that are so similar to human prints that even an expert struggles to tell them apart. It is believed that individual identification is possible in these animals as it is in humans, but further research is needed to confirm this. It was long thought that a fingerprint's ridge pattern improves grip, but this was since disproved. The real reason why we have them is still under debate, but there is a theory suggesting that they allow skin to deform, which stops ridged areas from blistering.

> *"Gorillas and chimpanzees produce fingerprints similar to our own"*

What's happening on... Twitter?

Make sure you follow us **@HowItWorksmag** for amazing facts, competitions and the latest in science & tech!

@cjayp33

I have enjoyed **@HowItWorksmag** from issue 1; I loved unlocking my unknown thirst for knowledge!

@katyamakukha

I'm glued to **@HowItWorksmag**, so glad I subscribed to it!

@Loopylouspurs

@HowItWorksmag #Sharks don't scare me but #spiders do!

@Ohcrawford

I love **@HowItWorksmag** because today they informed me there's a Japanese hotel with a robotic raptor receptionist!

@neiltyson

If Earth stopped rotating, everyone not bolted to the ground would fall over and roll due east at the speed of a jet plane.

@RichardDawkins

If you think evolution is "guided", you don't understand the first thing about evolution. If it were guided, we wouldn't need natural selection.

@NASA

Almost all we know about living in space ends at half a year. We're at that post as the #YearInSpace reaches halfway

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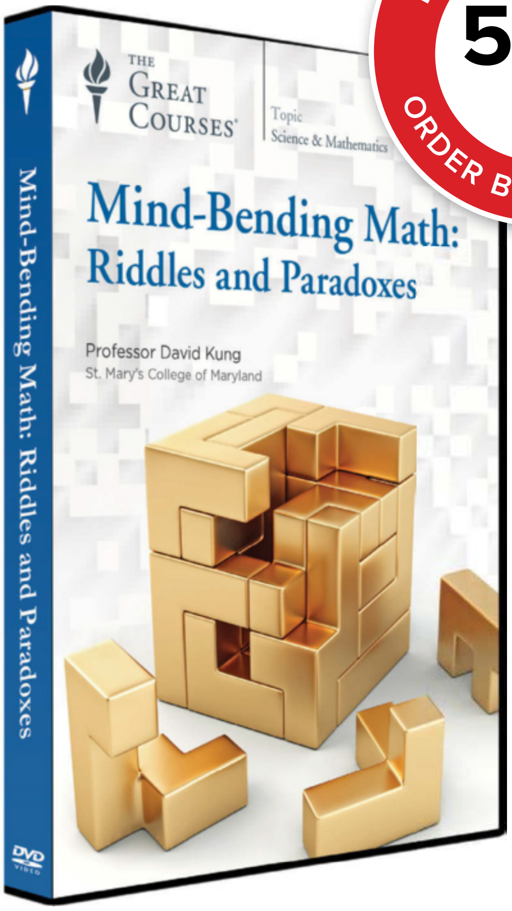

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